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Science in Tanganyika

By Reverend Vincent Deer, C. S. Sp.
EDUCATIONAL SECRETARY, NORTHERN PROVINCE, TANGANYIKA, AFRICA

All who read this unusual article will agree that while teaching science to native Africans is interesting and important work, it is no sinecure. Schools in this country complain about small budgets for science. In Africa, the budget, if it exists at all, is microscopic. The ingenuity of the teacher must take its place.

But lack of equipment is only one difficulty. Others are mentioned by Father Deer, one of the Fathers of the Holy Ghost Order who have been highly successful in their religious and educational work among the Africans.

In this account the writer draws upon a recent experience of seven years among the primitive people of the Tanganyika District.

Need of Science in African Schools

Most of the advances in the teaching of science are due to the research of recent years. All the reasons adduced by educators for science courses in the United States apply equally well to Africa. Perhaps I should say that these reasons apply better to Africa. Let us look at the life of the Africans and see.

REVEREND VINCENT DEER

Rev. Vincent Deer, a Holy Ghost Father in East Africa. African Missionaries in civilian clothes wear white or light gray for public appearances, or khaki for work or travel. The sun helmet is a necessity from 8 A. M. to 4 P. M.

Houses are built chiefly of mud, wattles and grass. Cattle are sheltered in the same houses with the people. Such houses make excellent breeding places for germs, insects and vermin in endless varieties. A fair number of diseases can be traced directly to these windowless homes. A scientist would probably be in his glory in one of these places, but that is no reason why the Africans should be allowed to continue to glory in them. Simple science if properly applied in the home would improve living conditions markedly.

Water also brings difficulties for the people. The chief water supply is from the rivers or irrigation furrows. Filtration plants are unknown, and would be ineffective without home plumbing. Simple hygiene is a necessary school subject. It is difficult to teach the people to use the springs of the country, especially when it means going another mile or so to draw water. It is nauseating to see them drawing water from the streams below bathing places. Yet that is not half so bad as to see thirsty children actually drinking in the pools while bathing. To uproot this custom one has to follow the best of scientific principles in education, for the danger is not one that can be measured, as in the case of insects.

Need I mention the dangers of milk? Americans readily appreciate them because so much has been done to obviate them in the United States. African children who sell milk in the towns are beginning to realize the necessity for care because they must present the milk at the local Health Office to be tested and approved before it is sold. What of the country people who are not affected by the law? Cleanliness is not practiced because the danger is not visible. The milk is stored in gourds; these are never cleaned, for the people prefer sour milk.

Meat offers its own hazards. Beef cattle are butchered anywhere in the open. The meat is not stored, for there is no refrigeration. There are no sanitary wrappings; in fact, it takes a long time to get cooks to wrap the meat at all. The boys carry the meat home on the end of a stick, and with the meat, of course, Africa's famous flies. That would not be too bad, if the meat were cooked well, for fire purifies; but most of the Africans merely char their meat, leaving the inside raw. As a result many have "worms." The schools must prevent this.

A further need for scientific training in the schools is seen in the multiple superstitions about the weather. As is almost universal among the primitive tribes, good and evil spirits are supposed to control the weather. The result is a certain kind of fatalism about crops. A parallel to our adage, "an ill wind blows no good," is the superstition that whirlwinds are caused by evil spirits, because of their extensive damage to the crops. Soil cracked by excessive dryness is supposed to emit evil spirits to ruin the crops as yet unplanted.

Scientific farming would open a wide field. The people are agricultural (except for some few nomadic cattle raisers.) Hence many need training in order to get the most out of the soil available for cultivation. In certain places land is already limited; that is to say arable land, because the agricultural people inhabit the fertile mountain slopes. Science must show them methods of soil improvement and conservation.

Instances of the need of science multiply almost indefinitely. So much so that I feel tempted to say that it is the most important subject in our curriculum. I have to be careful, however, and keep in mind the reason for my stay in Africa: Religion. Then, what about the three R's? Their place depends on the meaning of education. If education means a training for life, then maximum attention in Africa must be given to science after religion, and a minimum to the three R's.

A Beer Party beneath the banana plants. Beer, in this tribe, is made from overripe bananas and germinated grain (Elcusine coracana), and river water. It is ladled out of discarded cement barrels or hewn casks, with a gourd.

Previous Science Courses

Africa, or I should say, Tanganyika, got off to a bad start in science. Fortunately it was only a start of say, ten years, and, coupled with the limited number of schools, the damage was not great. Science courses formerly consisted of the routine studies followed almost all over the world some twenty years ago, and even yet followed in some places in the United States. Plenty of theory, mingled with facts to be memorized out of textbooks, and very little practical work, made up the courses. The courses were divided into various subjects and taught without any correlation. Hygiene, Physiology, Agriculture, Botany, Zoology and other subjects were taught separately. The chief harm, however, did not come from teaching without correlation but from too much theory.

A typical example that comes to mind is the case of a teacher giving a lesson on "Soil." The Inspector was in the class. He shrewdly asked the teacher if it was not advisable to take the students out into the garden to examine the soil for themselves. "No, sir," he replied, "These boys were raised on the soil and so they know all about it." That and various other instances taught us that teachers were relying on native knowledge not only about the soil but about science in general. They had been drawing on native customs for class material. As they lacked textbooks for their own country and having had inferior training, they could not be blamed too much for this. Nevertheless something had to be done.

New Course

All the school authorities submitted comments on the science course as it was being given and after some research and study by Education Officers, the science course was revised in 1934, and again in 1938. All science is now taught under the heading of biology. This title is strange, perhaps, but it is quite correct as it comes from a broader concept of biology. Biology is taken to mean everything that concerns human life. It can be seen that this limits science somewhat. That of course, is necessary in such a comprehensive field. Application is limited to African peoples and their needs. Only so much chemistry is taught as is required for the right understanding and improvement of home conditions. The same is true of botany, zoology, physics, etc. The greater part of the course is devoted to hygiene and agriculture.

Take, for example, the treatment of malarial fever in a class study. The pupils would be required to visit people sick with this fever. They would discuss the various sensations noticed when they had the fever themselves. They would tell of native treatment (cupping). They would examine the dangers of such treatment. They might contact natives who have suffered deafness and even blindness from delay or from improper treatment. They would learn the cause of the fever. They would study the carrier (anopheles mosquito), its life history, its annihilation, and its prevention. They would examine the advantages of early treatment in hospitals, and first aid in cases of necessity. Such a study uses a knowledge of civics, hygiene, medicine and biology, all so inter-related that it was a serious fault to separate them as had previously been done. The students are required to take notes as the study progresses, and the notes are corrected by the teacher at the end of the study.

The course is too long to give other details, but this one example will suffice to show the advantages of the new course. The pupils understand the work and get sufficient practical work to enable them to improve their home life. Vernacular students have two years study along these lines in the Fifth and Sixth Grades, while students in English have an additional four years' course. The English course has been advanced so much because it is hoped that in the near future all African teachers will be required to follow the English course before beginning their course in teaching methods.

Difficulties

For certain lessons in the course, African conditions present no difficulties. Everything necessary is at hand. An example would be the lesson outlined on malaria. A

Continued on Page Fifty-six

The Cook returns from the storeroom with his provisions—Beans in his shirt front, lard (ghee) in the bottle, and corn meal in the kerosene can. In about two hours dinner will be served by him in the shanty at his left. He and his companions call these shanties HOTELS.

The scene is in St. Patrick's Teachers' Training School, Moshi, East Africa. Shanties have now been replaced by a Pavilion designed by Father Deer and built under his direction.

The Academic Preparation of a Science Teacher

● By Rufus D. Reed, Ph. D., *(Ohio State University)*
ASSOCIATE PROFESSOR OF CHEMISTRY, STATE TEACHERS COLLEGE, MONTCLAIR, NEW JERSEY

Persons well trained in science do not always make good science teachers. Some may have had no professional training in Education. Others may lack an understanding of psychology and an appreciation of the true aim of high school science teaching. Many may be unfamiliar with the techniques of teaching.

Dr. Reed suggests a solution for the problem, one which we believe may eventually be adopted by institutions which desire to train both scientists and teachers.

It may be the only good way out.

●

In the preparation of a science teacher the following factors must be considered:

1. The raw material—The person who desires to become a science teacher.
2. The use to be made of the raw material—What does a science teacher do, and what does he need to know?
3. The means by which the raw material may be fitted for the task—How can the student best be trained to begin his work of teaching science? The education must be such that the teacher can not only succeed in his first assignment but also progress towards the ideal of a Master Teacher.

Selection of prospective teachers for junior and senior high schools is becoming more important as competition for positions becomes keener and as the art of teaching advances. Teaching is no longer an unskilled profession in which one may engage until escape is offered through entrance into business, law, medicine or matrimony. Nor is it a "way out" for the graduate of a professional school who finds that he is unsuited because of academic or personal unfitness. The prospective teacher should be selected on the basis of demonstrated ability in science, a desirable social and moral heritage, and demonstrated potentialities of leadership of young people.

Care in the selection of students will enable the college to devote more attention to the academic and professional preparation of the prospective teacher.

It has long been a misconception among college men that, in the main, high schools had teachers of chemistry, biology or physics who were teaching a single subject. However, studies of the range of subjects taught by high school and junior high school teachers made by Reed in New Jersey (1); Dunbar and Manon in South Dakota (2); Whitton in South Carolina (3); and Watkins in Missouri (4) all show that science teachers must expect to teach more than a single science, and frequently science-non-science combinations. The non-sciences most frequently taught by science instructors were mathematics, English and social studies. An unpublished study, made by Reed and Sister Gertrude Jose Smith, of the teaching of chemistry in the Catholic schools of northern New Jersey indicates that the leaching load in these schools does not differ materially from that of the public high schools.

General Science is very often a portion of the load of the biology, chemistry or physics teacher. General science delves into all fields of science. The new courses in physical science for the senior high school also require a thorough preparation in both physics and chemistry. The teachers of these courses must be competent to select suitable materials of instruction from both fields. The beginning teacher must take the extra courses in all the sciences while the more experienced teachers handle the work in a single science or in two sciences. The beginner must also assist in athletics, music, debating, guidance, club or some of the many extracurricular jobs in a modern high school. These facts indicate clearly that the college graduate with fifty to sixty hours in a single subject such as botany, zoology, chemistry, etc., is not prepared for science teaching jobs.

To meet this probable science load, Watkins recommended (4) "Students might well be expected to devote approximately 60 semester hours of undergraduate work to training in the sciences. If 20 semester hours are allowed for professional courses in education, the student will still have 40 semester hours or one-third of his under-graduate program to devote to general cultural courses outside of sciences." To meet the wide variety of science experiences needed by a science teacher this science preparation should be in all fields of science. It should be comprised of at least two years of biology, two years of chemistry and the same of physics. In addition, the student should have at least one-semester courses in astronomy and in geology. He should elect a third year's work in either biology, chemistry or physics. Assuming a year's course to be eight semester-hours and a semester course to be four hours, this prerequisite in science would require 64 hours of the 120 available. A portion of the electives should be used to develop a minor in either mathematics, English or social studies. Inasmuch as the physical sciences use mathematics as a language, it is highly desirable that students interested in these fields acquire a mathematics minor.

This undergraduate work should be in the fundamentals of each science rather than in the applied or so-called "practical" courses. Having a command of the

fundamentals of each science the teacher in service can increase his training in any field of science by appropriate courses. For a general science teacher this additional training may be in the applied science courses or in advanced work in a single field. For the biology, chemistry or physics teacher this in-service work should be in advanced courses leading to a Master of Arts degree in one field of science.

This undergraduate training would not prepare a teacher to be a research worker in biology, chemistry or physics. It would enable him to meet the ideal certification requirements which Gray (5) quotes from the recommendations of a chemistry department (6).

> "1. Ability to do reasonably independent work in chemistry.
>
> "2. Ability to utilize the chemistry library efficiently in obtaining information relative to a specific problem including ability to organize and evaluate such information in a critical manner.
>
> "3. Ability to present material, obtained on the basis expressed in 2, in a clear manner, whether orally, graphically, with demonstrations or in written English.
>
> "4. Ability to recognize the relationships which exist in the application of chemistry to other closely allied fields.
>
> "5. The ability to recognize the application of chemistry to everyday life.
>
> "6. An understanding of the basic principles involved in the organization of chemistry material for teaching purposes, a thorough realization of the distinctive type of pupil experiences by which skill in the use of the laboratory methods may be acquired and by which habits of thought in making analytical generalizations may be established, and a realization of the general parallelism between learning and research technics in the field of chemistry."

The non-science portion of a prospective teacher's preparation should fit the individual to be an intelligent participant in the social, economic, political, intellectual and religious life of the community. It should develop: (a) a realization of the social and economic changes which have occurred and are occurring, (b) the important role of science discoveries in causing these changes. Concerning this general education Rugg (7) makes the following statements:

> "A considerable portion—at least one-fourth of the total pattern should consist of general non specialized courses in the field of experiences.
>
> "General education should be based on the social and individual needs of students. It would appear, particularly until secondary education is modified to meet more satisfactorily the needs for general education, that the fields below should be represented
>
> a. Health and Science,
>
> b. Civic social responsibility and adjustments,
>
> c. Recreating and appreciation activities,
>
> d. Home and family relations,
>
> e. Philosophy and values.
>
> "Each field should provide for sufficient time and continuity to insure adequate grasp of survey courses in the field"

The professional or education courses for science teachers should enable the beginner to meet certification requirements. The general courses: (a) should furnish the student enough psychology to enable him to critically and understandingly evaluate educational articles and books in the science field. (b) Should present the philosophy of the junior and senior high school so that he understands the role of these schools in a democracy. (c) Should give him the techniques of teaching such as lesson planning, test construction, test administration and evaluation. The courses in science education should afford opportunity to know the published literature in the field. These professional courses should be accompanied by observations and discussions of the applications of these principles and devices and practices by "Master Teachers" in actual teaching situations. These observations are best made during the entire college course in connection with the education and science education courses. It is desirable that these observations be supplemented by the prospective teacher actually assisting the "Master Teacher" in preparing demonstrations or laboratory work. The professional preparation should be climaxed by an internship of several weeks. During this internship the prospective teacher should work in actual teaching situations under a competent teacher. He should be aided to adjust to this situation not only by the education teachers but, more important, by the science teachers from the college.

Close study of this program for the preparation of a science teacher at once indicates that four years is too short a time for the task. If one achieves the general culture, the preparation in science is inadequate. If this general preparation be slighted in favor of the sciences, then the teacher is well trained in science but lacks breadth of culture. However, if five years be allowed for the undergraduate work, the prospective teacher can be both proficient in science and adequately prepared in cultural subjects. Such a lengthening of education would not be excessive. The minimum for medicine is seven years. Many colleges of law and dentistry require six and seven years beyond high school for preparation. Twenty years ago many young men began to teach college chemistry after receiving a Master of Arts degree, while now a Doctor of Philosophy degree and even post doctorate research are considered essential. ●

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Presenting the Scientific Method to College Youth

● By William S. Webb, D. Sc., *(University of Alabama)*
HEAD, DEPARTMENT OF PHYSICS, UNIVERSITY OF KENTUCKY, LEXINGTON, KY.

Disturbed because in schools there is a diminishing interest in science—especially in physics—during a time of great scientific advancement, Dr. Webb decided to do something about it.

The traditional methods of instruction train specialists efficiently, but they fail to interest the average student. A new technique must be found. Planning wisely and proceeding carefully Dr. Webb devised a method that has already proved its worth in practice.

High school as well as college teachers of science will be interested in the writer's account of his successful experiment.

●

In this scientific age in which we live, characterized by rapid communication and transit and by a great elevation in standard of living, due to the manifold applications of science to the problems of daily life, the average man has come to accept these great advances as a matter of course, and has largely ceased to wonder at new developments or to concern himself with their origins. The ordinary college student seems to feel that telephones, radios, airplanes and mechanical refrigerators are quite natural objects which, like trees, mountains and rivers, have always been here. Such objects excite no special curiosity and offer no stimulation to his imagination.

This lack of intellectual interest in the inventions of science is, in part, the fault of science itself which, in order to bring its modern advantages to the average man, has so designed its products that no mental effort to understand processes, mechanism, or causes, is required of the user. Small wonder then that the youths of today, having on every hand advantages and conveniences that a generation ago not even kings and princes were able to enjoy, have come to be unimaginative, blasé, and grossly ignorant of the great forces at work in the world of which they are a part. If one may accept as a definition that the measure of a man's culture is his relation to his environment, and that man is most cultured when he is most efficiently and intelligently related to his environment, it appears that there is much to be desired in the present status of culture of the average man in this scientific age.

This lack of intellectual interest by the average man in the development of science of his own day may be due in part to the traditional methods used in the teaching of science, particularly physics. These methods, involving the use of the lecture, laboratory and recitation, have all been developed to educate the specialist. The techniques generally used often emphasize the difficulties of the subject, its exactness, its mathematical formulations and precise laboratory techniques. All these concepts are the "strong meat" upon which the specialist feeds in mastering a science, but they are not an acceptable diet for the average youth seeking merely a first-hand cultural acquaintance with the world in which he lives. By the average student, physics, in terms of its traditional techniques, is regarded as "hard," "uninteresting," "time consuming," and not worth the effort necessary to master it. It is thus a subject in the curriculum to be avoided at all costs. Few, if any, students in colleges, after an experience in physics in the high school, will voluntarily elect physics as a college subject. Only those register for it who *must* take it as a required subject. In most high schools physics is an optional subject, and in many schools it is not even offered. Thus, partly because our traditional methods of instruction in physics have been developed for the benefit of the specialist only, we have permitted the majority of our high-school students to graduate with little or no knowledge of physics, the most basic and fundamental science, the foundation of our modern age.

That the traditional methods of instruction in physics are efficient (as they should be) for the instruction of specialists is abundantly proven by the tremendous advances made in research and in the development of our natural resources. These advances in turn have resulted in the elevation of the standards of living. All this is as it should be, if research and development are to continue. But one wonders how long this scientific development may continue uninterruptedly if the great mass of our citizens who, having had the advantages of high school or college education, are left largely uninstructed as to the methods of science.

Some years ago, in considering this incongruity of a general diminishing interest in science at a time of great scientific achievement, the author became convinced that the traditional methods of physics instruction (as good as they were for the specialist) were quite inadequate for the masses and, as a result, the average student was avoiding the study of science much to his own loss and to the detriment of science. The conviction grew that science had much to offer to the average man, not only by way of furnishing him exact information of the world in which he lives, but also by offering him a "way of thinking," a "method of approach" to the solution of problems. This method of approach may be called the "scientific method." It is the simple, logical, effective process by which all sciences have been developed.

It is believed that, if the average man could be taught the scientific method, as exemplified in the science of physics, he might be led to adopt as a fixed mental

attitude this approach to the understanding of his problems. Professor Millikan* has expressed the idea thus:

> "We need science in education and much more of it than we now have, not primarily to train technicians, though that may be important, but much more to give everybody a little glimpse of the scientific mode of approach to life's problems, to give everyone some familiarity with at least one field in which the distinction between correct and incorrect is not always blurred and uncertain.
>
> "We need it to let everyone see that it is not always true that 'one opinion is as good as another'."

Here, then, was a problem in education. How could one put "science in education and much more of it than we have now?" How could the cultural value inherent in the scientific method be made to serve the non-technical student seeking a cultural or liberal education?

Since this non-technical student group had already manifested individual disapproval of the traditional courses in physics by regularly ignoring them, it was apparent that the educational technique could not follow the traditional pattern with much hope of success. These students could not, or would not, do satisfactory laboratory work individually. They have no interest in such activity since they do not wish to use such technical skills, and actually have no need for them. They do not need to know how a telephone receiver works in order to use a telephone, but if they can be brought to understand that a receiver is a kind of transformer which, in its action, illustrates the great principle of conservation, then the action of a telephone receiver becomes important as an illustration of the principle that man cannot really create, neither can he actually destroy anything. Laboratory instruction, therefore, was considered for them unnecessary. A second and important reason for its elimination was that, if the new approach succeeded measurably in its purpose, the number of students involved would be too great to handle in the elementary laboratory in the usual way without great additional expense.

Since the primary purpose of this new endeavor was not to teach physics as such, but to teach the scientific method, using physics with its great content of illustration as a vehicle, it was not possible to use exclusively any of the existing textbooks as a guide, but rather to use any or all of them as references for the particular matter in hand.

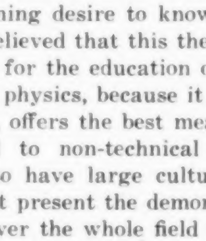
With the laboratory thus eliminated and the use of a particular textbook held in abeyance, there was no place left for the old "recitation" class which traditionally has often been regarded as a great bore by most students and by many good teachers. There thus remained of the old techniques only the lecture method. It was decided to modify this old technique to fit the new situation.

The lecture, as everyone knows, is commonly regarded by many as the most inefficient of all teaching techniques. The criticisms of the method are well known and need not be catalogued here. They are certainly valid if one regards the lecture as a means of communicating information. When used primarily for that purpose, it is a failure from the start. It is believed, however, that those who would thus criticize the lecture method, have missed the way to the solution of this vexing problem. The purpose of this new course is not primarily to *communicate information* although it may well do that, but it is to *arouse interest* in science by presenting the scientific method. As a means of *arousing interest* in science the well organized demonstration lecture is the technique "par excellence." It has no equal in effectiveness for this purpose.

The term "well organized demonstration lecture" may comprehend many things. It certainly includes effective demonstrations which are visible to every member of the class. This implies apparatus large enough to be seen, and the frequent use of projection methods. It also means apparatus which will *function without fail.* Any lecture which must contain an apology for the failure of apparatus had better not be given. Certainly in any one lecture all experiments should center about one idea, or at most, two ideas and all experiments should be so related that they illustrate various phases of the same concept. Furthermore, any concept thus illustrated should be selected because it is a worthy one, having broad generality, and the final truth expounded by the lecture obviously should be derived by application of the scientific method.

By means of a course of lectures planned to arouse curiosity and to heighten that interest, the student will be led to take his education into his own hands and begin—perhaps for the first time in his life—to develop in himself a burning desire to know WHY, HOW and WHERE. It is believed that this theory is a sound educational practice for the education of the non-technical student and that physics, because it is a basic and fundamental science, offers the best means of teaching the scientific method to non-technical students. Such a course appears to have large cultural and character-forming value. At present the demonstration lectures—about ninety—cover the whole field of general physics. These lectures are given three a week in groups of nine lectures, five groups each semester. It is the practice to give written tests for each group of lessons of the series. At each lecture the student receives a leaflet containing a brief synopsis of the lecture and a list of references to various textbooks provided in quantity in the library. Students are encouraged to write essays on topics selected by themselves but approved by the instructor.

During the first semester of 1939-40, the student enrollment in the University was 3,788. More than 12%, or 487 students, registered in this cultural course in physics, largely on a voluntary basis. This group is exclusive of the 449 students registered in the regular traditional physics courses common to all educational institutions of higher learning. ●



*Millikan, Dr. Robert A. "Who Gave Us Our Modern Wonders?" in *National Business*, March, 1929, while he was vice-chairman of the National Research Council.

Advances Through Scientific Research

● **By Edward R. Weidlein, Sc. D.,** *(Rutgers University)*
DIRECTOR, MELLON INSTITUTE, PITTSBURGH

For its outstanding accomplishments in pure and applied scientific research, especially in the field of chemistry, the Mellon Institute has achieved world-wide fame. Responsible in great part for its progress during the past quarter century is its present Director.

Dr. Weidlein knows more than any other man about what is going on in numerous areas of research. At the present time he supervises some eighty industrial fellowships in chemical and physical technology. He directs researches in the pure physical sciences, also.

Dr. Weidlein has an unusual store of information on which he draws freely in preparing this timely and significant paper, which was presented before the recent Duquesne University Conference for Teachers of Science.

If I were to select a text for my address, it would be, "It is research, it is science, that has put success on a foundation of fact, not opinion." Science contributed toward betterment of life by placing before us the desirability of facing the realities, or the facts, and of taking a broader and longer view with reference to everything in life. Science accords increased significance to truth, and, by causing more dependence upon it, leads not only to a better and more nearly stable and safer world, but to one in which the realization of forward building is enormously enhanced.

It must be remembered that it is only through useful knowledge that the people have gained the material blessings of our civilization. Every useful agent in our present life is the product of an industry, and it is only through the industries that new products of civilization can go to the people. New industries, such as the automobile, aircraft, radio, refrigeration, air-conditioning, and synthetic fiber, are children of science that are being continuously strengthened by research. Solely to radio the American public is indebted for hundreds of thousands of jobs, and new developments are constantly being made which create increased employment. With television available to many, who knows what the future holds forth? New medicines, new dyes, new uses for agricultural products, all come to us only through the industries. We often hear it said that some man eminent in science has "given" his results to the people. That is, in nearly every instance, nonsense. The Wright brothers' development of the airplane, Banting's discovery of insulin, could reach the people only through the industries.

Just as the three R's have given way to the breadth and depth of modern education, just as the old call for food, clothing and shelter as the essentials of life is now widened, so modern standards of living touch not a few but thousands of commodities, materials and needs. So long as man is man and his wants are beyond fulfillment, we shall never see the end of this ceaseless urge for discovery. Because of this transition, it may be of interest to study the cause. It is research that makes the wheels of civilization turn faster. Without it, industry and agriculture would not progress but would slow down and perhaps stop altogether. We have made only a beginning in utilizing for our needs the substances that nature has placed all around us—chiefly because of the many fundamental laws of science that still await discovery and stand as a beckoning challenge. There is, however, always uncertainty about the outcome of scientific research. If the results can be foreseen from the beginning, the work is not research at all. It is mental and not experimental effort. In every industrial research project, the result may be a success or a failure, or it may turn in an unexpected direction, perhaps quite unrelated to the business of the company concerned. This has indeed often happened. Research in industry is simply search, and then search some more, and, having done that, start searching all over again. In a changing world a business cannot stand still; it either moves forward or backward. If a company is motivated by accident, by outside pressure, or by guess, the business is probably doomed to failure. Three hundred years ago, Francis Bacon said, "If many useful discoveries have been made by accident or when men were not seeking them, no one can doubt that when they make it their business to seek and test, too, by method and order, they will discover far more."

Industrial research is looked upon as a new tool for industry but it actually began about seventy-five years ago, and systematic industrial research in the United States is thirty years old. The changes produced by steam, gasoline and electric power were just as revolutionary as the advances we are experiencing at present in the chemicalization of industry. The innovations which replaced hand power, thereby relieving human drudgery and intensifying the results of human effort came from the use of raw materials occurring naturally or, as in the case of metals, obtained by simple processes.

Through chemical research what were formerly considered as raw materials have been broken down and entirely new substances with more advantageous properties have been developed. As a result we have an interchangeability of matter instead of merely the interchangeability of parts in machines which brought mass production in industry. This distinction between the ultimate composition of things and their mechanical structure is of vital economic importance. In a compara-

tively short time it has greatly expanded the scope of man's inventive talents and has given a new definition to basic industrial materials. As long as we thought only in terms of engineering in our applied science work, man's chief energy was directed to inventing superior articles from Nature's products. From the time that scientific research turned to the composition of materials as a starting point, we began to see natural products not as raw materials by themselves but as sources of new raw materials present in abundance in the air, water, and the earth.

Chemistry has reduced the universe to 92 chemical elements or kinds of atoms, starting with simple hydrogen and going up the atomic scale to uranium, the most complex element known. All that we see about us can be resolved into these elements. It has been discovered, moreover, that four elements, carbon, hydrogen, nitrogen, and oxygen, make up the major portion of all things associated with plant and animal life. Coal and petroleum may be included in that classification. There are infinite varieties of ways in which these atoms may be joined together. United in one way they make useful textiles, and, in another, a nourishing food. In general, chemical synthesis was in its infancy in the United States in 1919, and chemical industry itself was just awakening to the enormous potentialities of scientific research.

More than 200,000 compounds have been created by this awakened industry and its research in less than a quarter of a century. The utilization of only a few hundred of these compounds has revolutionized the methods and products of more than a score of industries, effected changes in thousands of jobs, altered our food, clothing, and homes, transformed our daily habits, given new concepts to medical research, and established the United States in the forefront of scientific advancement, fortified it against war, and saved millions in money. The value of the products from the American process industries has increased from $2,000,000,000 in 1914 to over $10,000,000,000 in 1939. According to the United States Department of Commerce, the output of chemicals and allied products stands below only foods, textiles, metals and metal products.

The expenditures for industrial research in this country have increased steadily. Reliable estimates credit the 2,000 industrial research laboratories with staff totaling 34,000 scientists and 16,000 assistants, operating at an annual expenditure in excess of $215,000,000. Every major industry of today offers convincing proof of the value of past research accomplishments and particularly of the ability of the research worker to discover new truths which industry can utilize. The gains already recorded have been the result of comparatively small expenditures, for, high as is the total cost of research at first glance, it really represents less than one per cent of the gross receipts of industry and agriculture. Yet, of all those employed in industry today, one-fourth are engaged in phases of manufacturing which did not even exist in 1880, when research was a rarely used tool.

Through chemical synthesis we have established national self-sufficiency in nitrates from the air, in dyes, and in most drugs. Just to cite a familiar instance, camphor, an essential material, is now made from southern turpentine. The life of our petroleum deposits has been doubled and possibly tripled, with the result that the threat of an oil scarcity has been deferred for a long time.

In speaking of the broad reliance on chemical research, a few illustrations of developments during 1939 will indicate the progress that has taken place.

Ten years ago iso-octane, the arbitrary 100 in the anti-knock scale for rating motor fuels, was only a laboratory reagent and sold for about $30 a gallon. Today 20,000,000 gallons of this compound or its fuel equivalent are being purchased by the aviation industry at one one-hundredth of the 1929 price. The present plant capacity is 37,000,000 gallons and additional plants are under consideration, which will bring the total quantity up to 125,000,000 gallons annually.

The chemical industry is constantly developing products to make our national position more secure and today with an emergency existing we would not have to look with fear upon being shut off from some essential raw materials, such as rubber. Instead, we can manufacture from coal, water, salt, and limestone a product, "Neoprene," that in some respects is superior to rubber. High wartime prices for natural rubber may combine with lower production costs for the "synthetic rubbers" and thereby widen appreciably the field in which new synthetics can compete with the natural product. Plasticization of "Neoprene," "Neoprene" cements, and vulcanized "Neoprene" and its modifications were developed during the past year. There has also been produced an odorless "Neoprene" which will induce its use in the household. Hydrocarbons, of which there is a plentiful supply, such as ethylene and butane, have also been demonstrated to be sources of elastomers of synthetized rubber substitutes. New latex cushionings are being extensively employed in the seats of airplanes and automobiles. A new rubber-like material was produced during the year by the polymerization of isobutylene to create polymers having enormous molecular weights. These elastic fibers are said not to deteriorate as rapidly as those of rubber. They may be dyed by appropriate means and, when coated with any of the usual textiles, may be woven into elastic fabrics resembling the covering material. Such fabric is said to be suitable for clothing. Chlorinated rubber products have been improved and as a result have found wide application in industry. Advances of importance have in fact been made throughout this particular field during the year.

A purely abstract discovery in an obscure laboratory today may be the germ leading to a great industry tomorrow. A good example is the synthetic plastic industry, which has grown at a great pace and has created thousands of steady jobs. The list of new materials being considered and utilized for new plastics is amazing. This includes such materials as derivatives of by-product coking, proteins from alfalfa, sawdust, wood pitch, natural gas and other substances too numerous to mention. An imposing series of patents have been issued during the year and each patent issued seems to create a new idea for further patents.

Metallurgical progress has been profoundly affected by the improved relationship now existing between steel companies and their customers. New steels are being made to meet specific needs. The outcome of this investigational work is that certain substances, until lately regarded as highly undesirable in metallurgy, have proved remarkably beneficial in conferring improved properties at relatively low costs. The favorable light in which phosphorus is now held is perhaps the most surprising example of this change. Long avoided as a treacherous impurity, it is utilized at present as an important inhibitor of various forms of corrosion. Phosphorus also imparts greater strength to steel for a given cost than any other element. Today, with improvements in welding technics and with the production of stronger, more corrosion- and abrasion-resistant steels, it is possible to produce lighter weight structures. The excessive weight which has been such a substantial factor in the cost of transportation is thereby avoided. The modern passenger train, for example, weighs one-third less than its predecessors because of the proper distribution of scores of different materials in its construction, many of which were unavailable until recently. Research makes for obsolescence, thus creating new opportunities for workmen. Even a new mechanical innovation, which may temporarily displace labor, will in the end increase the demand for labor to supply the requirements of the broader market created by the machine. One of the outstanding developments during the year was the introduction of small amounts of silver to stainless steels which has improved the resistance to salt-water corrosion. Silver, moreover, is said to improve the rolling and machinability of the metal.

About $10,000,000 was spent by the steel industry for industrial research. Approximately 2500 scientists are employed, while close to 1300 others devote part of their time to investigational activities. About 33% of the expenditure is devoted to the improvement of the quality of products and 19% is spent in the betterment of manufacturing methods. The development of new products represents about 20% of the activities. The steel industry has invested more than $9,000,000 in providing facilities for its research workers.

In every field each improvement in technical practice is making industry more dependent on the laboratory and is taking the laboratory deeper into the realm of the fundamental science concerned.

Glass is a case in point. The remarkable properties of the new "Hi-Test" safety glass for use particularly in automobiles, is a tribute to science and industry and another illustration of the progress that can be effected through concentrated research effort. To humanity the benefits of such a development are enormous, for it will prevent uncountable tragedies. This new safety glass, made from rubber-like "Vinal" plastics and plate glass, is a material of great strength under all temperature conditions but is also sufficiently yielding to reduce passenger injuries on impact. This product is largely used in the 1940 automobiles.

That science in industry has helped to make living safer and more comfortable is due to the coordinated efforts of a large number of capable men. Laminated safety glass is the result of the efforts of many workers, coordinated through sound research management. The problems that have arisen in bringing this product to its present state of perfection have been shared and solved by many specialists; ceramists who worked out suitable formulas for both glass and refractories; engineers who devised processes and equipment for casting, grinding, and polishing plate glass as well as methods for constantly reducing the thicknesses of the glass so made; chemists who developed the plastics that have been used in the interlayer and who evolved the plasticizers that go to render this interlayer flexible; chemists and engineers who invented compositions to make some of the plastics used adhere to the glass and solved many problems involving the fabrications of the laminated glass itself so that it could be produced economically in usable quality. All these scientists contributed valuably to the art as we know it today. As is quite usual in such cases, the perfection of the product has not taken place in a uniform manner. It was sufficiently useful in its early forms of development to fill a definite need and so it was given to the public as the best available. Research continued, however, and suddenly discoveries came that markedly improved the product. In consequence, a new and better laminated safety glass is now available through the efforts of five of our leading industrial concerns, following an expenditure of $6,000,000.

An important development in the field of structural glass has been accomplished by the design of a new glass block containing a sheet of "Fiberglas" sealed into the block. The insertion of the "Fiberglas" increases the insulating value of the unit and makes it of particular interest where a well diffused light is desired combined with the other advantages of glass-block construction. A typical unit of the newer design transmits 55 per cent as much energy as the older block and 75 per cent as much light with a marked increase in light diffusion. "Fiberglas" insulation is also said to permit a substantial reduction in the size and weight of motors. Moreover, motors so insulated may operate at higher temperatures than those with other types of insulation.

An ultra-low expansion glass has been evolved which promises the possibility of manufacture by mass production method of glass cooking utensils having properties superior to previous glass dishes and at a reasonable cost. It is prepared by leaching out of a special glass the non-siliceous components, leaving a network of nearly pure silica which, by baking at high temperature, fuses into a completely transparent glass resembling fused quartz. It is extremely resistant to breakage under violent temperature changes. This development has not yet been carried to the commercial stage.

Optical glass, which is very essential to our instrument makers, has been constantly improved. Scientific tools are essential to the success of any research program and we have made such remarkable progress during the past few years because of the improved tools which we have to work with.

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Chemical Gardening

● By Regina L. Kelly
ST. ROSALIA HIGH SCHOOL, PITTSBURGH, PA.

This essay was selected by members of the faculty of Duquesne University for the gold medal award in the 1940 national science essay contest for students in Catholic high schools conducted in connection with the University's annual Science Conference. A suitably engraved silver cup for one year's possession has been awarded Miss Kelly's school.

Sister M. Josephine, I.H.M., and Sister M. Macrina, I.H.M., supervised the essay.

Because of the merit of the entries in this year's contest, the judges awarded honorable mentions of equal value to the essays submitted by six other schools. The names of the students so honored, their supervising teachers and schools were published in the March, 1940, number of this journal.

It is true that a benevolent Providence watches over us, but it is equally true that God expects us to take advantage of the means of progress placed at our disposal. Thus it is that reasoning creatures turn to science for assistance. This essay aims to show the help given us through CHEMICAL GARDENING, one of the greatest of all popular-fancy-catching scientific processes.

Today, all over the country, "gardeners," from amateurs to skilled agricultural chemists, and from garden-hobbyists to enterprising commercial growers, are operating "chemical gardens" that testify to the possibilities of this soilless growth of plants.

Because of the magic-like rapidity with which interest in this process has grown, and because of the publicity given to it recently, the impression is likely to be created that this nutrient-solution-culture is cloaked in mystery, or is an entirely new discovery. Both these implications are false. The growing of plants without soil is neither mysterious nor new.

The soil, after all, is only a medium from which plants extract certain necessary chemicals — nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, known as "fertilizing" elements, and iron, manganese, boron, zinc and copper, known as "trace" elements. Those of the former group must be furnished in relatively large proportions (as 1 part each in 5000 parts of solution), those of the latter, as the name implies, must be present in very low concentration.

Now if these essential elements are made available to the plant roots by some other means than soil, the soil is no longer needed. Nutrient salt solutions are just such a source of plant food. So much for the lack of mystery attending soilless horticulture.

Now as to the age of the procedure.

As early as 1699 Woodward grew potatoes and spearmint in water, but he failed to grasp the true significance of water culture. By 1840 the French chemists, Baussaingault and DeSaussure, had experimented successfully in growing plants in sand and charcoal saturated with solutions of phosphates, nitrates and sulfates of potassium, magnesium and iron. By 1850 the German Von Sacks had proposed the nutrient-solution formula, which, with slight modifications, is in universal use today. By 1865 the German Knop had brought Von Sacks' formula into such usage that he, Knop, is usually referred to as the originator of liquid culture.

Soilless culture as a laboratory method of research into plant ailments and fertility, then, is nearly a century old! However, the refinements and adaptations made within very recent years by Dr. William F. Gericke, Dr. D. R. Hoagland, Dr. O. E. Arnon, Dr. John

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Post-Gazette Photo

For the first time in the four years that Duquesne University has been offering a silver cup to the high school student of the nation who writes the best essay on a scientific subject, the cup has come to Pittsburgh. The winner in this case is Regina L. Kelly, a senior of St. Rosalia High, who is pictured, right, with Betty Anne Shanahan, her class president, left, as she examines her name, now engraved on the cup along with names of other winners from other cities. Regina also won the gold medal she wears.

The Value of Exhibits in High School Science Teaching

● By Reverend P. H. Yancey, S. J., Ph. D. *(St. Louis University)*
DEPARTMENT OF BIOLOGY, SPRING HILL COLLEGE, MOBILE, ALA.

Here is a somewhat different angle on the use of projects in high school science.

Father Yancey believes that the planning and preparation of exhibits is of value not only to the student but to the teacher and the community as well. He feels that project making arouses interest, trains students in cooperative enterprise, and stimulates research.

"It keeps the teacher from getting into a rut."

This paper was read before the Science Section of the Alabama Educational Association at its 1940 meeting.

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It has been estimated that two-fifths of all our experiences are received through the optic nerve. Therefore, it would seem that there could be no doubt about the value of exhibits in stimulating interest in the teaching of high school science. I suppose that most high school teachers agree with this in principle. But, unfortunately, only too many fail, for various reasons, to carry it into practice.

Usually when we say that something is of value in teaching, we mean that it is so for the student. Of course it should be primarily, since it is the welfare of the student that education has principally in mind. However, since even teachers are not always wholly altruistic, they are inclined to take more interest in things that also redound to their benefit. In these days of "service," some are best moved to action by the thought that what they are doing may result in some good to the public. Well, it is my conviction that the use of exhibits in high school science teaching is good not only for the students but also for the teachers and the general public.

The benefits accruing to the students arise from several sources. The first, of course, is facilitation of the learning process. As teachers we naturally want our students to learn as readily as possible. It is pretty well established that for most people visual impressions are more striking and more lasting than others. This is attested by the fact that a good deal of our terminology for learning is couched in words referring to vision, such as "seeing," "perceiving," "showing," etc. The ancient customs of depicting ideas with images and of telling stories by acting them out, both of which have been combined with such remarkable results in moving pictures, also prove the point. Educators have always taken advantage of visual aids to teaching as is shown by the use of illustrations, models, etc. Now the teaching of science is particularly suitable for the use of visual methods since we are dealing with material, extended objects and processes involving movement. And of course, the use of demonstrations is a *sine qua non* for successful science teaching.

However, the employment of visual methods of any kind is not an issue here, but rather of the exhibit. By an "exhibit" we understand a demonstration or model of some object or process prepared by the students themselves. Has this any special value in teaching over and above the appeal to the visual sense? Yes, it has.

In the first place, the planning and preparation of exhibits arouses interest. Except for a few unusual students, ordinary class lectures and even demonstrations and laboratory work are uninteresting, if for no other reason because they are class work. But the making of projects has some of the interest of a game in it. Students forget that they are working. Science courses cease to be simply subjects that must be "gotten through" somehow, and instead, become subjects of preference. Of course, if not properly directed, such project making might cause the degeneration of the science courses into manual training, but a good teacher will always keep before the students the purpose of the projects and will use them as means towards the end of inculcating the principles of science. While manual training is not the purpose of our science courses, nevertheless some training in the use of tools is also useful to the future scientist, and to any man. In the preparation of exhibits, too, there is valuable training in the art of display which may prove helpful.

But it is not only interest that the planning and building of projects arouses. It stimulates creative work. What are all our great inventions but "projects," that is, the application of scientific principles for practical purposes. In training students to build projects we are setting them on the road to becoming inventors, that is, practical scientists who as they learn more and more of science will see more and more ways in which it can be made useful to mankind.

Another advantage to be gained from the preparation of exhibits by students is training in cooperative enterprise. This is important both in science and in life in general. Many of the greatest advances in science have come about through the united efforts of several scientists, working on different parts of some problem. Two heads are better than one. Often a single individual, no matter how brilliant, fails to see difficulties that are at once apparent to some one else, and difficulties which seem insuperable to one person may easily be solved by another. Then, too, in the planning of any project different persons will have different ideas, some good and some poor. By pooling these and selecting the

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The American Society of Amateur Microscopists

● By Julian D. Corrington, Ph. D., *(Cornell University)*
PERMANENT SECRETARY, A.S.A.M., PROFESSOR OF BIOLOGY, WASHINGTON COLLEGE, CHESTERTOWN, MD.

Here is an account of a worth-while activity for teachers and pupils interested in microscopical work. Amateur and professional alike are invited to join this new organization which already has enrolled some 500 members. One-fifth of them are high school students.

Teachers may find it desirable to have their most capable and enthusiastic student microscopists join this Society. They might even consider the installation of a local Chapter.

Dr. Corrington tells how to proceed.

●

A long-felt need in popularizing science in America has been met by the formation of a national organization for all classes of people interested in microscopy. As is well known, such amateur societies have long flourished in England and had a considerable vogue in the United States during the latter half of the nineteenth century. They have largely died out on our side of the Atlantic except in larger centers. New York, Chicago and a few other big cities have their microscopical societies but the movement declined in general and sporadic attempts to revive interest have failed.

More recently the introduction by manufacturers of miniature and inexpensive models of microscopes has brought such instruments within the means of students of high school age as well as adults who could not or would not invest larger sums in a hobby, and a number of magazines have carried popular articles on elementary microscopy.

Among these is *Nature Magazine*, a publication of the American Nature Association in Washington, D. C., which, in the August, 1937, issue began a regular department, entitled *Under the Microscope*, conducted by the writer. After a year, the numerous following built up was sounded out on the proposition of establishing a national organization, and the questionnaires then sent and returned yielded a satisfactory response. The society was officially launched in the March, 1938, issue, the writer taking the position of Permanent Secretary, while Dr. Simon Henry Gage, of Cornell University, accepted the first presidency. Dr. Gage is one of the best known living microscopists and author of *The Microscope*, now in its sixteenth edition.

Subsequently, printed application cards took the place of the old mimeographed questionnaires and a very attractive emblem was designed. It appears on the certificates sent to all members. Publication of a mimeographed *Bulletin* was begun, the first issue comprising a roster, and the second including fifteen articles that were very well received. About four issues per year are planned, depending on funds available from new memberships. They will feature articles on all phases of microscopy, graded from very elementary to quite advanced, in order to appeal to every class of reader.

The A.S.A.M. has attracted over 500 members at this writing, including persons from all walks of life. Of these, 20 per cent are of high school age, 20 per cent of college age, and 60 per cent are adults beyond the college years. Almost every conceivable occupation is represented: college and high school teachers and students, with a representative number from Catholic institutions; officials and workers from the CCC, Boy and Girl Scouts, Government agencies, hospitals and research centers; optical manufacturers and biological or apparatus supply houses; doctors, lawyers, business men and women, artists, clerks, farmers, railroad men, mechanics, salesmen and laborers; married women, stenographers, nurses; persons on relief or out of work. Indeed, microscopy is a universal hobby, appealing to both men and women and to young and old. Nearly every state in the Union has at least one member, with sprinklings from our foreign possessions, Canada and England, Cuba and South America. Both professional and amateur microscopists are welcome, the only requirement being an interest in the subject.

Teachers will be especially attracted by the aid rendered through the installation of local Chapters of the society which function as community microscope clubs. Some of these are general, for all members in a town or city; others center around high school or college biology departments, or a research center or factory in which workers are encouraged to prosecute leisure time hobbies. The State Microscopical Society of Illinois, in Chicago, one of the oldest scientific groups in the country, has affiliated with the A.S.A.M., and other such unions are contemplated. Chapters have been installed or are being organized in many parts of the country. Each Chapter is provided with a handsome charter, an instruction manual for the organization and conduct of a local club, including many practical suggestions on programs and activities, and with literature and other aids from national headquarters, not the least of which is the selection of a suitable instructor to supervise the chapter work.

The advantages of such a national body are many and obvious. Probably first in importance is the publication of the *Bulletin*, with articles written by the members themselves. Organizing all of the persons in a given community or school who have similar hobby tastes brings them together socially, stimulates by example and team work, permits ownership of expensive property not available to the average individual and furnishes means to undertake group projects or research, field trips, public exhibitions, and the like. An

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Research Pays its Own Way

● By H. L. Russell, Ph. D., *(Johns Hopkins University)*
DIRECTOR, ALUMNI RESEARCH FOUNDATION, UNIVERSITY OF WISCONSIN, MADISON, WIS.

Workers in any field of education will be interested in this account of "a new step in the development of higher educational effort."

The University of Wisconsin is a leader in the protection against misuse of the inventions made by its staff members. The Alumni Research Foundation aids the staff in the preliminary phases of their work, secures patents for discoveries when such protection seems desirable, maintains laboratories to control the quality of its licensed products, and utilizes any resulting profits to support scientific work at the University.

This interesting article tells how research can be made to pay its own way.

In 1925 a Professor in Biochemistry in the University of Wisconsin* made an exceedingly important invention. It related to the effect of ultra-violet light on certain organic substances. By exposing such chemical compounds as certain sterols to the influence of these short-wave rays that are below the visible spectrum, he was able to produce Vitamin D, that remarkable growth-accessory substance which is so essential in the proper development of bones and teeth. A lack of this necessary factor in the food supply is associated with the disease of rickets, that scourge of early childhood.

It was at once obvious that a discovery of this character could be so readily misused that in some way the invention should be controlled, to prevent its unwarranted exploitation. Here was an entirely new method of treatment, that was a definite improvement over the administration of cod liver oil which empirically had been found to be efficacious in the treatment of rickets. Not only could a new medicinal product be developed by the use of the ultra-violet rays, but this beneficial quality could be imparted to food products as well.

Dr. Steenbock, the inventor, decided that the most feasible way to prevent the misuse of his discovery was to apply for a patent. He could have readily disposed of his discovery by selling his application to some pharmaceutical house or a food concern, or he could have organized a private corporation for the specific purpose of commercially developing his invention and pocketed the profits. In fact several flattering offers were presented to him but they were all turned down.

To the Board of Regents (the controlling corporate body of the University) he offered the invention, feeling as a professor in the institution at which the discovery had been made that any possible profit that might come from the use of the invention should be devoted to public rather than private interest.

It is apparent that the Regents of a state educational institution who give their time gratuitously to the administration of the University as a trust are hardly in a position to develop the necessary machinery for the commercial development of a patent. At this fortuitous moment, the idea was presented to the Regents by a group of the alumni of the institution that a private corporation might be organized for the purpose of commercially developing, not only the Steenbock patents, but any other discoveries made by members of the University staff where it seemed desirable to secure patent protection. The declared object of this corporation, however, was to utilize any possible profits for the support of scientific work at the University and not for the benefit of the inventor. The Board of Regents approved the plan, realizing that it was a much more workable device than it would be for them to attempt to organize a business corporation in their own body.

Wisconsin Alumni Research Foundation Organized

In this way the Wisconsin Alumni Research Foundation came into being in 1925. At that time the idea was more or less unique in connection with the development of universities. It was really an experiment in social development that broke new ground.

Many commercial concerns have long held the opinion that research could be made to produce adequate returns on the money invested, but in these cases, the end in view with the research undertaken is specifically directed toward better and cheaper methods of production or the origination of new products. Manifestly such ideals could not be set up in an educational institution where the pursuit of science should not be governed by such utilitarian objectives. It is only now and then that a discovery or invention is made in universities that renders it desirable to consider the advisability of patenting.

Experience now for ten years has indicated the desirability of such an organization. The Research Foundation acts as a clearing house for staff members where they can secure aid in determining a proper course of procedure. Scarcely a month passes without some staff member bringing to the Foundation the germ of an idea that he has developed. More frequently than otherwise the idea is hazy and indefinite. The first thing that he wants to know is, is the idea new, is it sound? The Foundation has the legal facilities to determine by a patent search in the files of the United States Patent Office whether or not the idea suggested is novel.

It is an old saying that there is nothing new under the sun. Often in making this technical patent search, it is found that the discovery has been anticipated by some one else. If the preliminary search indicates that prior art does not exist, the next consideration is to

*Dr. Harry Steenbock

elaborate the idea more completely by necessary experimental effort to reduce the invention to actual practice. Generally, it is a long road from the formulation of a crude idea to the point where the invention has been perfected and reduced to actual practice, where working models have been made.

The Foundation labors under the very great handicap that the suggested inventions that are presented to it cover the entire field of scientific thought. One day it may be an improvement in electrical engineering in the welding of pipes; the next time, a chemical preparation that is the outgrowth of a laboratory process. Manifestly no single Foundation can be equipped to aid by laboratory or pilot plant procedure, such widely separated scientific activities. In this respect the Foundation itself is much less favorably situated to carry to completion the further investigations required than would be the research department of a commercial organization whose field is naturally limited to the particular line in which the corporation is interested. To remedy this inherent defect the Foundation has to seek the aid of commercial concerns that are equipped in the special fields in question. This Foundation has found no difficulty in making such necessary connections wherever it seemed advisable.

Patents Already Acquired by Foundation

Since the organization of the Foundation, 19 U. S. patents have been assigned to it voluntarily by staff members of the University. A half dozen or more applications are now before the Patent Office for consideration. In the case of some of the inventions, patent protection in a number of foreign countries has been solicited and granted. Four of these patents and applications have now been reduced to practice and are being commercially operated.

The Steenbock Irradiation Patents

By far the most important are the Steenbock patents for the irradiation of foods and medicines for the production of Vitamin D. Five of the leading pharmaceutical houses in the United States were licensed to manufacture and sell irradiated medical preparations marketed under the name of Viosterol. The general medical acceptance which these products have received has led to their widespread use, with the result that a rachitic condition in infants and children is now largely prevented from development.

Under modern conditions of living, the natural source by which human life receives its protective Vitamin D supply is greatly reduced from that available to more primitive man. Smoke, soot and dust in the air over our large cities practically exclude the possibility of absorbing Vitamin D from direct sunlight. During much of the year the sun's rays fall so obliquely on the most populated parts of the earth's surface that direct absorption is greatly reduced.

It so happens that foods in general are strikingly deficient in Vitamin D. To some extent this essential growth element is found in milk fat (hence in butter), and in the yolk of eggs. Meats, cereals, vegetables and fruits, while containing a number of other vitamins are so deficient in Vitamin D that it is of much importance to consider the fortification of certain food materials with this growth factor. While the Research Foundation has been continuously importuned to permit the Steenbock process to be used in the treatment of all kinds of foods, beverages, cosmetics and miscellaneous products, it has steadfastly adhered to the basic principle that the process which it controls will be licensed only for use in such generally used foods as bread, milk and breakfast foods. Milk is susceptible of fortification, either directly by irradiation with the mercury vapor or the carbon arc lamp, or previously irradiated material may be added conveniently to fluid milk. At the present time Vitamin D fortified milk is available in every city, town or hamlet throughout the length and breadth of the land. Over two and one-half billion pounds of the milk that is now used in the evaporated milk industry are treated by direct irradiation without any increase in the cost of the product.

Foundation Checks Products of Its Licensees

The Foundation maintains control laboratories (nine of them throughout the United States) to check and control the uniformity and potency of its licensed products. Large commercial concerns maintain a service of this type for their own protection, but an independent check is also maintained by the Foundation at an expense of over $50,000 a year. This service is wholly for the further protection of the public.

Other Patents in Commercial Use

In addition to the extensive business operations that the Foundation carries on under the Steenbock patents, commercial operations are in progress with the Hart copper-iron patent for the treatment of nutritional anemias; also with the method of stabilizing iodine in salt and mineral mixtures intended for animal feeding, and with several applications that are now pending before the Federal Patent Office.

Unique Feature of the Foundation

In the above capacity the Foundation is carrying on its business in a manner comparable to many other organizations. The distinctive feature which makes the Foundation a different type of corporation from other business concerns is the way in which it disposes of the realized profits.

The ordinary corporation is created for profit. If it is successful in its operations, its stockholders participate in those profits through the declaration of dividends and the accumulation of surplus to be used in further expanding and developing the business.

This Foundation declares no dividends; its trustees (a governing body of seven alumni of the University) receive no compensation for attendance upon the monthly meetings of the Board or committee assignments. After the Foundation is recouped for its out-of-pocket expense in securing, developing, maintaining and defending a patent, any net profits are invested by its Investment Committee, and the income derived therefrom made available to the Research Committee of the University for the support of specific lines of research, establishment of scholarships and fellowships (post-

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Plant Hormones

● By Ruth M. Esser.
DEPARTMENT OF BIOLOGY, ROSARY COLLEGE, RIVER FOREST, ILLINOIS

Plant hormones and hormone-like substances influence growth, the swelling of tissues, the induction of adventitious roots, cell growth, and the production of fertile hybrids. They produce other important effects.

Here is a brief, up-to-date account of their nature, occurrence, and action, written by a senior student in the department of biology at Rosary College. It contains much material of immediate interest.

This paper was prepared under the direction of Sister Mary Ellen O'Hanlon, O.P., Ph.D., chairman of the department.

●

A hormone is defined, simply, as a physiological messenger. It is a chemical substance actually produced in one part of an organism, sent to another part, and there, even in very low concentrations, influences specific physiological processes.

As a general rule, plant hormones which influence growth are called growth substances, specifically, plant *auxins*, the term being derived from the Greek word which means growth. Plant auxins are formed naturally at the very tip of the growing stem and other actively growing plant parts; there this growth-producing substance is made from a half-finished product called "auxin precursor," after which it is sent to the region of elongating cells—the point at which growth takes place.

The term hormone was first introduced about 1902 into animal physiology where it applies to a great number and variety of chemical messengers which exert various physiological influences. In 1910 the term hormone was carried over into plant physiology, at which time it was discovered that plant development, too, is also controlled by these physiological messengers. Since that time the knowledge of plant hormones has steadily increased.

The current uses of the terms *hormone*, *growth substance*, and *auxin* are wide and over-lapping. In the present paper the general term plant hormone will apply to any chemical substance, natural or synthesized, which exerts one or another physiological influence on growing plants.

Just as shocking to the world as would be the invention of a method to grow hair on a bald head, was the discovery of the role played by hormones in plant development. Following this discovery of naturally-produced hormones and their effects in plants, chemists have succeeded in synthesizing substances which produce the same effects as the hormones which are naturally developed. These synthesized chemical messengers are prepared in large amounts from both plant and animal materials. Notable among the animal sources are some familiar gland secretions—saliva, pepsin, and human urine. Among the plants which contribute "source material" are fungous cultures—such as Rhizopus, the common black bread mold, and Aspergillus spp., the blue, green, and white molds which grow on fruits—also maize (corn), some other molds, and certain bacteria.

Some of the substances which are injected or applied in experiments with plants are indolebutyric acid, napthaleneacetic acid, indoleacetic acid, auxin-a, auxin-b, colchicine, vitamin B_1, and many others. Continued research will without a doubt discover and produce more and more new substances which may be used artificially to produce the effects of natural hormones.

Among the effects produced by hormones and hormone-like substances are the acceleration of growth, the bending of stems and leaves, the swelling of tissues, the induction of adventitious roots, the production of fertile hybrids, cell division, and the like. Some of these substances inhibit the above mentioned responses, depending upon the part of the plant to which they are applied or the various environmental conditions under which the plants are growing. In other words, these artificially produced substances are really hormones, physiologically speaking.

It is well understood that water is absolutely essential to life, but like many another good and necessary thing, in excessive amounts it is harmful and even destroys life. So too it is with the plant hormones. It must be a *definite hormone* applied to a *specific part* in exactly the *correct amount* which will give the best response. Too much may inhibit growth or cause death; too little has no effect. Knowledge of the optimum conditions is acquired through slow, persevering, and painstaking experimentation.

Professor F. W. Went, California Institute of Technology, in a Sigma Xi lecture, *The Regulation of Plant Growth*, compared the hormone system in plants to the democratic system of checks and balances w ch is the pride of American constitutional development. The democratic system, Professor Went pointed out, is paralleled in plants by an order of internal secretions or

LEGENDS FOR FIGURES

Figure I. Taxus cuttings showing rooting of cutting after treatment with indolebutyric acid.

Figure II. Tomato plants with the tops removed. Cut surface of stem of treated plant rubbed with salve of naphthaleneacetic acid.

Figure III. Carnation cuttings: control plants and those treated with indolebutyric acid.

Figure IV. Jerusalem artichokes showing effect of treating tubers with naphthaleneacetic acid.

Figure V. Holly showing parthenocarpic development after exposure to methyl naphthaleneacetate. Note on the controls the withering of floral parts and on the treated plants the parthenocarpy and persistance of petals.

CONTROL TREATED CONTROL TREATED

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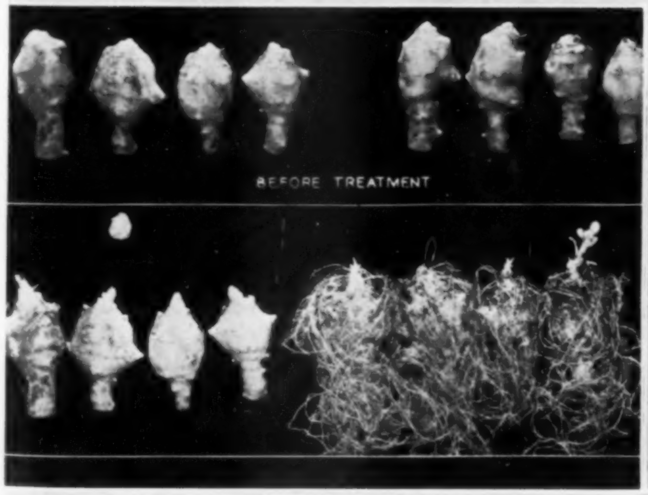
III



CONTROL 21 DAYS AFTER TREATMENT

IV

CONTROL 9 DAYS AFTER TREATMENT

CONTROL 16 DAYS AFTER TREATMENT

CONTROL 22 DAYS AFTER TREATMENT

V

(Courtesy Boyce Thompson Institute of Plant Research)

hormones. Thus growth and other processes in one part are stimulated, but kept under control by other parts of the plant organism. For example, mature leaves develop a hormone that influences the growth of younger leaves and auxins that promote root growth are manufactured in the tips of growing shoots. Even though an all-dominating central control is absent, the parts of a plant may be said to live in a state of democracy.

Plant Hormones and Roots

The induction of roots and the acceleration of root growth is so far probably the most important use made of synthesized plant hormones. Much experimenting is in progress with cuttings of various plants and, in the majority of cases, the induction of roots is successful and their subsequent growth is accelerated. Roots have been made to grow luxuriantly on cuttings of the holly and the lemon, both of which, as a general rule, are very stubborn about naturally rooting and must therefore be propagated by the much more expensive methods of grafting or from seeds. Roots also have been made to grow profusely on stem tissue of treated plants, as shown in Figure II.

In the propagation of carnations considerable success has been obtained by the root-induction method. Although most varieties can be rooted successfully without treatment, the treated carnation cuttings root from two days to one week earlier if the correct amount of root-inducing substances is applied; moreover, the induced root systems are larger than those naturally produced (Fig. III).

Treating various plant tubers with synthesized hormones is another phase of root-induction. The tubers of the Jerusalem artichoke lend themselves very effectively to this experiment and the root systems produced are extensive (Fig. IV).

As with all other plant hormones the responses produced by root-inducing hormones are greatly modified according to the plant species and such conditions as temperature, humidity, season, age of the plant, and the supply of food materials. Therefore, miracles cannot be expected in every trial. Experiments made on cuttings from native as well as cultivated gymnosperms, for example, Taxus, the American Yew (Fig. I), have given surprisingly successful results. It is important, however, to point out here that the best results are obtained from cuttings taken in the late fall and winter, the least satisfactory results being from those taken in mid-summer. Thus the interaction of many factors are responsible for the best results and the optimum conditions can be learned only through experiment.

Polyploidy

Since chromosomes bear the genes for the various hereditary factors, if and when the chromosome numbers are doubled, tripled, quadrupled, such factors as determine growth will by their increase in number naturally speed up growth. Plants which bear multiple numbers of chromosomes are called *polyploids* and are generally "bigger and better" than those plants which bear only the normal number of chromosomes.

The colchicine method of increasing the chromosome number in plants has been employed quite extensively in practical plant breeding in many vegetables and flowers. Colchicine is a hormone which is extracted from bulbs of the common autumn flowering crocus *(Colchicum autumnale* Linn.). Mr. Gordon Morrison of the Ferry-Morris Seed Company has experimented widely with colchicine and the zinnia plant and reports excellent results. Successful results are also being obtained from colchicine treatment of tobacco and many other plants.

Plant Hormones and Parthenocarpy

In most plants the development of fruits is simultaneous with the development of the seeds they contain. Certain plants, however, for example, the navel orange, the seedless grape, and the banana, develop fruits naturally without fertilization. Such fruits are generally seedless. This phenomenon called *parthenocarpy* occurs sporadically in nature and was for a long time puzzling to plant growers. It is now known, thanks to the investigations and direction of plant physiologists, that the development of the fruit depends upon the presence of hormones in the plant or in the pollen. In certain plants pollen, even foreign species or extracts of pollen, if applied to the ovaries of their flowers will produce seedless or parthenocarpic fruits artificially.

At the present time induced-parthenocarpy is receiving much attention by plant hormone investigators. Professor Felix G. Gustafson of the University of Michigan was among the first to experiment with synthetic substances to induce parthenocarpy. Professor Gustafson reported the production of seedless tomatoes, peppers, egg-plants, cucumbers, etc. Other experimenters (Gardner and Marth) induced parthenocarpy in holly berries and strawberries. Still others have induced parthenocarpy in various other plants.

Associated with induced-parthenocarpy is the retardation of floral development. Recent investigations have been made by Drs. P. W. Zimmerman and A. E. Hitchcock of the Boyce Thompson Institute by applying vapor from synthetic naphthaleneacetic, indolebutyric, indoleacetic, and phenylacetic acids to the flower buds and the open flowers of the American holly (*Ilex opaca Ait.*), fuschia, and orchid plants—all of which were grown from cuttings. Potted holly plants flower freely, and because this plant is unisexual (dioecious) and therefore impossible to be self-pollinated, it is a particularly suitable subject for this experiment. On the other hand, it is necessary to keep the plants bearing staminate and pistillate flowers in separate greenhouses in order the more surely to prevent insect pollination.

The holly is a close relative of the grape and therefore might be expected to respond to parthenocarpic-inducing hormones. The flowers of the American holly do not all open at the same time, the earliest flower often being a week ahead of the others on the same branch. This condition also facilitates this experiment, since the buds may be treated at the same time in various stages of development.

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Making High School Science More Productive. Part I.

This paper, and the two that follow, formed a part of a Panel Discussion on "Making High School Science More Productive" that was presented at the 1940 Duquesne University Conference for Teachers of Science in Catholic high schools. Very Reverend Raymond V. Kirk, C.S.Sp., Ph.D., President of Duquesne University, acted as Coordinator.

Three other papers from the program will appear in our next number.

Classroom Teaching Techniques

by SISTER CLARETTA EASTER, O. P., M. A. *(University of Wisconsin)*, St. John's Cathedral High School, Milwaukee, Wis.

Christ, the greatest of teachers, used the every day means and methods at hand, as is evidenced in biblical accounts; and it is still good pedagogy in this modern age to reach the student through the medium of his daily experience. It is my purpose in this paper to go one step further and suggest that we apply only those teaching techniques that are ultimately fun. To do which, we the teachers, must come down off our pedestals. (The idol's clay feet will not show so readily from the lower level.)

Our general topic is, making high school science more productive. For whom? For the student, the parent, and the teacher. By what means? Obviously, classroom teaching techniques, fair or foul. For what purpose? To pay dividends: physical, intellectual, and spiritual to student, parent, and teacher. Technique! Just what does the word mean? Webster says, "artistic execution." Probably that is exactly what my methods amount to—execution.

In the history of education we find that five methods of subject matter presentation have been used. First, individual instruction, second, the Socratic method, and third, the cold storage method (learning by rote), that many of us still use at times, fourth, the lecture method, which will not do, because teachers tend to become oratorical, and fifth, teacher-pupil lecture-demonstration. Most of us use a combination of these, for they all have their good points in certain situations.

Now, there are three techniques for presenting this subject matter. First, the practice technique. By practice we generally mean skill acquired in muscular and motor co-ordination. There are hundreds of things teachers do to develop this skill, this ability in their students. You cannot win a football game by blackboard practice only; nor by spending hours tackling the dummy just the day before each game. So if we are to teach motor and mental skill in science we must provide directed practice. A strong talking point for laboratory work.

The second is the problem technique. Thought presupposes a problem. Study is thinking. To secure such thought the teacher must present problems that tax the best efforts of the students. Questions, and lots of them are essential in presenting the problem technique. Leads must be given to show the way to the solution.

The third is the participation technique. Here is where the teacher must be enthusiastic, and share his experiences with the students. Dr. Cunningham of Notre Dame University says, "The curriculum is made up of three types of subjects: science, appreciation, and arts, and three techniques each appropriate for the achievement of the aim of one of these three groups of subjects." It is the problem technique which is the most used and the most appropriate to science teaching, although I feel that all three are essential.

Don't forget that, "Knowledge is gained from books, but the love of knowledge is transmitted only by personal contact," and that "it is not *what* you study, but with *whom* you study that matters." It is with this latter quotation constantly in mind that I plan my classroom teaching techniques. Accordingly, then, the fundamental requirement of satisfactory teaching technique can be expressed in that one vital word—Life. The one way to secure such a program is to bring 'em back alive! What do I mean by bring 'em back alive? Applied to your lecture period, take them with you, but bring 'em back alive; to your parent demonstrations, bring 'em back alive! To your field trips and industry excursions, bring 'em back alive.

Application of the practice technique is made chiefly in the laboratory and through student demonstration work. During the recitation period, however, flash cards, dice and card games are some of the means I use to develop mental skill. These flash cards of sea foam green, recognized by authorities in the Sight Saving Department of the Chicago public schools as the color most suited for the eyes, contain the formula on one side, the chemical spelled out on the opposite side. The dice, two to a game, bear positive and negative radicals. These when rolled may form compounds, Na - Cl, K - OH, etc. If a compound shows and the player can name it instantly he rolls the dice a second time. A trump compound may be thrown and the game played as progressive bunco. Where get the dice? Have the carpenter cut some cubes of light wood. Burn in the symbols with an electric stylus, or paint the cubes black and use white letters. The unpainted ones wear better.

The card game consists of about one hundred sea foam green cards, the size of ordinary playing cards. Two cards each of fifty chemical and common names make up the deck. The chemical names and symbols are painted in black, the common names in red. The cards are dealt to four or six players, and played like Old Maid or Donkey.

There are hundreds of ways of using the problem technique. The project method, "enterprise" is the later and more preferred term, supplies a competitive urge, teaches self-reliance, initiative, resourcefulness, and provides for individual differences. For several years my combined physiology, biology, and chemistry classes have staged a scientific convention conducted exactly as is the A.A.A.S. A full account of this attempt you will find in *School Science and Mathematics* for October 1938. Printed programs contain an orderly chronological schedule of events. Delegates lecture, round table discussions are held, there is a guest speaker, always a noted scientist, conducted tours of the exhibits, and excursions to nearby points of scientific interest are planned. A speakers' luncheon and a theatre party are the high lights of the social amenities. The convention serves as a complete review for the science students, a revelation to many outsiders and an incentive for those students who are doubtful about their electives for the coming year. Talk about correlation, motivation, teacher preparation! You will get them all if you undertake a science convention. This is definitely problem and participation technique. It is fun, too.

Other enterprises that grew out of the project method as we used it, were Bible study for plant and animal references, flower and garden shows, the annual pet show, and our campus planting.

Finally, we consider the participation technique. Making science function in the local community is part of the teacher's task in making high school science more productive. It pays to advertise. And do we advertise! The physiology class goes in for a clean up of home medicine cabinets. They collect from the doctors' offices samples of patent medicines, read the labels, and discuss the harmfulness or uselessness of the contents. The result is an expose of harmful drugs and the patent medicine industry. A student written article concerning this problem is accepted by the daily paper. Fond parents discuss the subject over the bridge table, vieing with one another in their eagerness to laud their Shirley or Suzanne for the effect of her campaign on Dad's Alka-Seltzer habit, and Mother's choice of cosmetics.

Meanwhile the biology class enters the city garden show with constructed front elevations of model homes and real yard plantings done on a miniature scale, wild life protection models, trap setting for destructive animals, and plant conservation exhibits.

Not to be outdone the chemistry class sets out to show how scientific research has provided leisure, supplied money, and conserved energy for the enjoyment of better things, for better living, which it has created. A Cruise on the Crucible of Chemical Change took the parents out for a nautical night, demonstrations in household chemistry being the general theme. They showed that although at one time "the colonel's lady and Judy O'Grady were sisters under the skin, rayon and other synthetics have brought even a closer kinship between the famous pair, making them sisters over the skin."

Applying the participation technique gives the teacher ample opportunity to satisfy her creative urge. During education week this year we had a novel event. Students taught parents. The parents attended class, donned rubber aprons, and tried to juggle test tubes, bottles and flasks in preparing some non-metallic elements. This period was followed by a bunco and card party at which the dice and cards mentioned earlier were used.

An effective testing device can be worked out by using the participation technique. Correcting reviews of the students' required reading takes too much time and is not any fun. So we had a literary tea at which students and parents discussed their scientific readings of the previous month. It is surprising how interested the participants become in this informal reviewing. Some of the boys had read "The Jungle" by Upton Sinclair. One set of parents, former residents of Chicago, grew most enthusiastic in their defense of the Chicago Stock yards. So eager were they to prove that Sinclair's book had brought about a reform, that they made a date to drive a car load of boys to Chicago. At this literary tea the table decor was all chemical—a Kipp generator, in which floated flowers, served as a center piece, paper towels, all nicely monogrammed with chemical formulas, were the napkins, beakers with stirring rods made excellent cups and spoons, and copper boilers held sucrose and cream. A florence flask on a tripod heated by a bunsen burner provided the hot H_2O for the tea, with which were served cakes frosted with alchemistic symbols of the elements.

Tests on the text book are administered weekly. These call for brief answers, but are so worded that yes and no answers cannot be given. Sometimes I divide the class into sections A, B, C, D and E, each section answering the one question specified for that group. At the semester all science examinations are held at the same time. The seating can be so arranged that no two students of the same subject occupy adjacent seats.

Later a formal tea and symposium on the tri-scourges of man will climax the season's activities. Incidentally, we Cathedral Chemists have music as a hobby, so this very formal occasion will boast a string ensemble. Correlation? Participation? Yes, and fun.

Our present concern is a student-written laboratory manual. Being camera conscious we are taking the pictures for it, as well as writing the directions and then following them in the laboratory. We hope eventually to produce a really artistic, scientific, and pleasing book. This *is* fun.

These three methods that we have been discussing have been set up by the teaching profession as the criteria of successful teaching techniques. But they are older than the profession itself. An investigation into the methods of the Model Teacher will show that He used the problem method. "For if you love them that love you what reward shall you have?" Or again He says, "Were not ten made clean? And where are the nine?" He constantly asked questions of His disciples and left the answers to their own reasoning powers. "What went you out to the desert to see? A reed shaken by the wind?" "If the salt lose its savor wherewith shall it be salted?" "Or what exchange shall a man give for his soul?"

The story of Christ's method in convincing the doubting Thomas is a lesson in participation technique. "Put in thy finger hither, and see My hands and bring hither thy hand and put it into My side, and be not faithless but believing . . ."

There are no tricks to the trade. Each teacher works out her own devices. These of mine you may find useless. But a firm knowledge of the principles, some ingenuity in the choice of devices, and a heart overflowing with the joy of living does the trick—that is, puts the theory into practice.

Summing up then, science must be made more productive for student, parent, and teacher by means of adequate and varied teaching techniques, for the primary purpose of paying dividends—dividends physical, intellectual, and spiritual. Is our teaching paying dividends? Do our methods simply teach science or do they also teach the value and importance of living as social beings, the ability to think, and to meet life situations with logical reasoning? Or are we merely producing wooden-headed Charlie McCarthys, helpless without their Edgar Bergens?

Since we live in a personality conscious world, it becomes our duty to develop the full personality of the child. He is a physical, intellectual, and spiritual entity. And so these dividends of which I speak are paid in full if satisfactory and up-to-date techniques are used.

The physical dividends that our teaching should pay to the student are:

1. Awareness of the loveliness of God's creation.
2. Awareness of the loveliness of his own body.
3. Development of his realization of what that body is for. Possible objections to the last point on the grounds that the child may be too young are overruled by the consideration of the Virgin Mary's reception of the angel's message.

The intellectual returns to the student are appreciative and understanding interest in cultural agencies purely for the refining influence they have on the mind. In this the home as well as the school must assist.

Finally, the spiritual dividends. An education that is truly Christian will bring to student, parent, and teacher the consciousness of the indwelling of the Holy Ghost. Realization that the student has an inherent right to these returns on his education, and that every teacher has the capacity of imparting such dividends will make of each of us a thrilling, pulsating, vital, joyous personality. ●

Motivation in the Teaching of Science

by BROTHER EDWARD OF MARY F. S. C., B. A. *(La Salle College)* Central Catholic High School, Pittsburgh.

Since there are many viewpoints from which we can consider motivation, we might well begin our discussion by defining the term as we intend to use it here. "Motivation," says Webster, "is a stimulation to active interest in a subject by appealing to associated interests or by other special devices." In other words, it is that special enthusiasm, incentive or drive which will induce the pupil to learn because he "wants to learn" and not because he is "forced to learn." We all recognize the principle that "the student learns best what he is most interested in," but all too frequently we sacrifice this principle to the ever pressing problem of covering a certain amount of subject matter in the time allotted. We are inclined to teach the subject rather than the pupil.

Now just what part does motivation play in the process of learning? In our studies in education we learned that three factors are involved in the learning process: a psychological factor, a physiological factor, and an environmental factor. The psychological factor is motivation. It is the very heart of the learning process. Adequate motivation not only sets in motion the activity which results in learning, but also sustains and directs it. Reflection, interest, effort, all the outcomes most desired by the teacher and most valuable to the pupil, are a result of sufficient motivation. The average pupil works below his maximum capacity because of this lack of adequate incentive to learn. Therefore it is one of the most important functions of teachers to produce situations and develop attitudes resulting in strong desires which the pupils will attempt to satisfy. The desire for new experience, the desire for information, the desire for skills and attainments which will result in the appreciation (and perhaps the envy) of their associates, will assist in bringing about desirable activities on the part of the pupils.

When and how shall we motivate our pupils? In regard to the subject taken as a whole, motivation should begin the very first day. During the first few lessons, when classes are so unsettled, we might profitably discuss the possible applications of our science to the everyday life of the pupils, instead of immediately rushing into an explanation of new technical terms which their previous inexperience might make too difficult for them readily to comprehend. I have found it helpful to bring to class on these days several full page advertisements culled from various trade magazines, illustrating various phases of the chemical industry. These serve as central points for discussion, and are an excellent means for arousing interest in the subject matter of the course. Pupils are given an opportunity to express themselves. They feel that they have something to contribute to the discussion, and this feeling of participation not only helps them more quickly to adapt themselves to school life again after the long summer vacation, but also makes them better able to appreciate the wide scope of this science and the part it plays in their daily lives.

Motivation should play an important part at the beginning of each new unit of our subject. We must provide the necessary incentives to urge the pupils in seeking the answers to those problems in the unit which natural curiosity has inspired. As a means of accomplishing this, I would recommend following the method as outlined by Sister Mary Ida, S.N.D., in her excellent article entitled: "Motivation of a Unit on Insects" which appeared in the December 1939 issue of the

Science Counselor. Essentially the method is to allow the pupils to organize the objective of the unit *under proper direction*, and then proceed by various means to solve the problems and difficulties presented by the unit. It is to be understood, of course, that the teacher must so direct this phase of the work, that the goals set up by the pupils are in keeping with the educational objectives of the course of study.

In brief, then, all our work must be directed toward creating an abiding interest in the pupil, leading him to sense a problem, and then to proceed by the methods of science in solving that problem.

What are some of the ways of stimulating interest in science?

1. The use of good, motivated assignments.

Pupils ought always be assigned operations of a useful character, and the value of the assignment should be pointed out to them in advance. For example, in chemistry, after completing the first day's discussion as mentioned above, we might follow up by making an assignment to list those chemical products used by the pupil from the time he gets up in the morning until he arrives at school. This gives even the student who has failed to enter the discussion of the day, a chance to express himself, and at the same time the assignment is extrinsically motivated by the friendly rivalry which results in trying to list the greatest number of items.

2. Wisely selected demonstrations.

Increased interest is secured by occasionally allowing student participation in demonstrations where no new technique is needed or where there is no possibility of danger. Waning interest may be stimulated by use of startling demonstrations, but as a general rule it is better to avoid bizarre effects.

3. The use of biographical accounts and research narratives.

One of the aims of science education is to give the student an appreciation for the progress mankind has made in attaining knowledge of the world about us, and of the use of that knowledge in alleviating some of the sufferings of humanity. Therefore, we should take every opportunity to relate incidents in the lives of the great scientists, and have pictures of them placed in classroom and laboratory, so that our pupils may be inspired by their achievements.

4. Introducing students to the literature of science.

Many popular books and magazines on science are available, and it is up to the teacher to acquaint the pupils with those which are most likely to develop interest. Encourage oral (or written) reports on science articles read during their leisure time. It might be well to mention here, the keeping of scrap-books, the posting of up-to-date articles on classroom bulletin boards, and other similar devices for keeping before their minds the problems of science and how they are solved.

5. The use of *visual* and other *sensory aids*.

Motion pictures, slides, stereographs, flat pictures, models, graphs, charts, trips to industrial plants and the like—all serve to emphasize the importance of the science being studied and will surely stimulate interest. And finally—

6. The presentation of interesting problems in the form of projects.

Some of these should be carried out during the process of studying each new unit, but inasmuch as students will vary in their interests we should permit them to choose from a list of selected topics at the beginning of the unit. The more practical we make these projects the more interest will be created.

Apart from those projects directly connected with a particular unit, we might keep a list of a few simple problems which may be given to those pupils who show special ability for this type of work. By referring to these special projects as "Research Problems" we lend added importance to the work, thereby intensifying motivation.

This paper does not presume to exhaust the entire list of means by which motivation may be intensified and directed. Its purpose is merely to furnish a convenient summary of the most obvious, the most frequently employed auxiliaries in the teaching of science. Out of them it is hoped may grow additional ideas and suggestions that will be of practical assistance to all teachers of science in the high school.

Better Correlation

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In this age of over-specialization there is great danger of efficiency in subject matter overshadowing productivity in related fields, that is, we are inclined to stress assimilation of facts, acquisition of specific skills, high grades in examinations, rather than development of mind, of character. Correlation hopes to achieve broader goals in the various subjects: not mathematicians, but mental discipline; not geometricians, but logical reasoners; not scientists, but scientific thinkers; not artists, but aesthetic development; not dramatists, but an understanding of the drama in life, or even ability to judge a good "movie"; not geniuses, but saints.

Perhaps, one may ask (relative to the transfer of training) if each subject is thoroughly mastered does not correlation automatically follow? The answer to that question depends upon many factors among which are: techniques, procedures, conviction of the worthwhileness of the skill, ideals, maintenance of high level of attention, etc. Psychology teaches there is no isolated item in the consciousness: that the human mind generalizes experience, interpreting the present in terms of the past. But amid so many distractions of today, to the untrained high school student, associations are purely arbitrary and of little value. Hence, each new problem must be linked with as many related ones as possible. This technique will give to the student a back-

ground of basic attitudes of orientation, so that when confronted by similar difficulties he will know the general classification and method of attack: the foundation of clear, accurate, independent thinking.

Science and Religion, Ethics

In any true Christian scheme of education there is a regular ascension of the mind: from the concrete to the abstract; from the real to the ideal; art to science; science to philosophy; philosophy to religion, the supreme integration of all knowledge. Instead of being leaps from one isolated water-tight compartment to the next, these become, through correlation, series of gradual adjustments whereby students come to the realization of God's Truth, Beauty and Goodness imprinted upon all science.

The difficulty, of course, is that our youth, preoccupied with elaborating schemes for this world, are not cognizant of the fact that the plans were all made for them ages ago. All a Christian should do is pray for light and strength to know and follow God's plan. But students cannot *see*. Their metaphysical telescopes are sadly in need of adjustment by prayer and the sacraments. The telescope, fashioned to view distant objects, when focused upon what is near distorts the image; the mind of man, made for the spiritual, the eternal, when continually fastened upon the material or the transitory, falsifies the object. Therefore, stress the spiritual; teach the *soul* behind every fact of science. Matter and energy are prototypes of the dualism in man, body and soul. Consider one form of energy, the lightning. Unharnessed and unleashed, it works havoc and ruin; but captured, tamed, pressed into service, it lights our fires, cooks our food, turns the wheels of industry. The dynamic forces within man, lawless, and rebellious, spread disaster and destruction; but, restrained by self-discipline, they accomplish moral miracles compared with which all the triumphs of modern science are a mere pretension. . . . . .

Science and English

In all written and oral assignments there is a general carelessness in fundamentals; punctuation, syntax, capitalization, spelling, pronunciation, enunciation, etc. We have such mental cripples that they cannot find words to convey their thought when giving an exposition of a demonstration. Let us seek causes. Skill in expression depends upon clearness of thought which cannot be had without precision and exactness of definition—(the Scholastic ideal). Hence, why not correlate with the English department, the head of which may set up definite standards of attainment for the content subjects. Continued violations may be referred to the teachers of English because theirs is the responsibility for imparting the technique of speaking and of writing in the vernacular. We refer not to scientific nomenclature, the task of teachers of science, but to the ordinary English words which students can neither spell, pronounce, nor understand. To build up a scientific vocabulary, "sales talks," such as are heard over the radio, basing the worth of a product upon some scientific experiment, may be utilized to good advantage. This procedure enkindles imagination which furnishes intellect with the materials for its operation and therefore plays a very important part in the assimilation and organization of scientific knowledge. Let judges decide whose talk is most effective to arouse competition and interest. These powerful catalysts will accelerate skill in expression for when sufficiently interested one can always find words to convey the thought.

Science and Greek and Latin

Since the Rennaissance it would seem that English has lost the power to coin new words out of native elements.

Hence, since we no longer have the old-fashioned Etymology embodied in the curriculum, it would be wise to correlate with the classics in order to instil a knowledge of prefixes, suffixes, and roots. Where there is deliberate association little difficulty is presented in the following: anode, cathode, endothermic, exothermic, symbiosis, chloroplasts, photosynthosis, ion, efflorescent, deliquescent, heterogeneous, homogeneous, isotonic, hypertonic, hypotonic, potential, kinetic, etc. Knowing the root or prefix, the student may acquire the habit of analyzing each new word and predicting its meaning. Its enjoyment makes for mental economy and minimizes the technical difficulty of teaching science. Then, too, since so many students do not wish to enroll in the Greek and Latin courses (following utilitarian standards) the teacher of science may stimulate interest in the classics; for we have need of the mental vigor derived from their study if science would rear a stable superstructure.

Science and Mathematics

From all teachers of science we hear that students do not know fundamental mathematical concepts. Errors in problem solving are rarely in advanced skills, but in addition, subtraction, decimals and fractions. Lack of accuracy and failure to analyze a problem are deplorable. Why not solicit the aid of the department of mathematics, requesting drills upon basic concepts, as well as problems of the machines, solutions (mixtures), direct and inverse ratio, equation, substitution, clearing of fractions, etc.? In geometry there are certain constructions which may be linked with phases of physics as, making an angle equal to a given angle, parallelogram of forces; erecting a perpendicular, total reflection; similar triangles, elementary trigonometric relationships, with index of refraction, locating images in mirrors, etc. Also, the methodical procedure of geometry should be related to laboratory work. It is told that Abraham Lincoln, after learning three theorems, sat back, folded his arms, closed his eyes and said: "Now, I know what it means to prove a thing." He was applying his geometry to his daily problems. Perchance, through correlation, we may achieve this desired goal.

Science and History

The teacher of history has a real mission to perform that will make high school science more productive: to disprove the opinion current even among some educationists, that the gifts of science today are solely destructive, citing birth control and the European war as

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Scientific Research

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Imported silk, bristles, gut and other similar products will soon face "Nylon" and "Vinyon," home-bred competitors which will ask no handicap. In order to bring "Nylon" into general commercial production as soon as possible, $2,500,000 is being spent on plant extensions at Belle, W. Va., for making "Nylon" intermediates, and $8,500,000 on the erection of a "Nylon" textile plant at Seaford, Dela. The production of "Nylon" in this plant will be sufficient to supply 10 per cent of the silk stocking market. One company is planning to produce sewing thread of "Nylon," termed "Neophil." It is reported that dermal sutures of "Nylon" have been used in 20 hospitals with good results. These sutures are dyed so that the threads may be located easily. "Vinyon" is now being marketed by several companies, one of which is producing a high-quality felt. "Vinyon" is particularly well suited for use as industrial filters and for raincoats, fish lines and nets, boat sails, and bathing suits. It is strong, elastic, and capable of being spun exceedingly fine. "Teca" is the name of a family of cellulose acetate rayon staple fibers, characterized by an inherent stabilized crimp, which are now in commercial use. "Etho-Raon" is a new fiber, a substitute for silk in the manufacture of hosiery yarn. Sulfite pulp made from Georgia pine is said to be satisfactory for the production of viscose rayon.

These achievements are the results of long-range group fundamental research which has been carried out with continuity and patience. This type of research should be encouraged. If business is taxed to the point where the officers have to cut down on their research programs, it means a death blow to fundamental research, which will delay our return to prosperity.

A report from Japan which appears in the February 10 News Edition of the *Industrial and Engineering Chemistry* states: "Announcements of 'Nylon,' Vinyon and other American-developed synthetic fiber products have caused considerable stir in Japan as likely to usher in a textile era in which Nippon's ancient silk industry will be doomed. Thirty years ago, when rayon made its bow, the Japanese had a similar problem. They licked it by establishing a rayon industry of their own, since grown to the world's largest. What part of their silk market they lost to rayon was amply compensated. Now, as then, the Japanese hold that it makes no difference whether silk is produced by worms or platinum nozzles, if only they are able to produce and sell it."

The question has been raised of the efficiency of industry under democracy. The answer is that no nation anywhere, whatever its form of government, has surpassed our own either in the quantity or quality of new materials or products of industrial science. The United States has equaled if not excelled Europe in achievements in the coal-tar dye, related chemical, and high explosives industries, and in the synthesis of high-pressure products based on coal, water, and air. The latter now number more than 100, of which some of the new textiles are examples. Others are produced from natural gas and petroleum products.

Under date of February 10, Dr. Arthur H. Compton, Nobel Prize winner, issued a very noteworthy statement from Berkeley, California.

> "Operation of battleships by atomic energy was intimated as a future possibility by Dr. Arthur H. Compton of the University of Chicago, 1927 Nobel Prize winner, during a visit here with Dr. O. E. Lawrence, last year's Nobel Prize winner and inventor of the atom-smashing cyclotron.
>
> The progress being made in the smashing of atoms by the cyclotron, and which thereby releases the energy in them, is of more importance to the world today than the war in Europe," Dr. Compton declared.
>
> The energy in the atoms is that used in the sun and stars. It is hundreds and millions of times greater than all the rest of the fuel now available in the world.
>
> 'Already the science of releasing this atomic energy has advanced to such a state that one of the greatest worries of scientists at present is what to do with it, once it finally becomes available.'
>
> Dr. Compton pointed out that one of the greatest elements to be considered in the release of atomic energy is that there can never be any corner on atoms, such as can be brought about on coal and oil, but that there can be a corner on the understanding necessary to use their power.
>
> On this point, he declared, the United States has the greatest chance of obtaining such a corner, for the work necessary to arrive at this knowledge is now being accomplished in this country. It also is here that the progress is greatest."

It is believed that, through orderly and persistent research, industry will also be able to absorb many of the surplus crops of American farms. Cellulose is "stored sunshine." The alchemists talked of storing sunshine, the English speculators of the time of John Law floated companies for the purpose; the chemical industry of the future will harness sunshine in the form of agricultural by-products and convert them into useful materials.

Cotton, the paramount crop throughout much of the South, has suffered grievous setbacks within the past two decades. Foreign outlets have been curtailed, domestic consumption has declined. To meet such a situation, which ultimately would spell economic disaster to many people engaged in various aspects of the cotton industry, all available remedies must be applied. One of the most trustworthy is that productive tool of industry, scientific research. When properly employed it can be relied upon to find new uses, to maintain present outlets against competition from other commodities.

Realizing the urgent need for action, a group of earnest men dedicated themselves to the task of organizing a broad program of investigation on cotton utilization. The Cotton Research Foundation, organized in 1936 by private individuals, has taken upon itself the responsibility of financing a research program, started in 1937, for the improvement of an industry as a whole through scientific research.

During the year 1939, as a result of the successful research program inaugurated, the National Cotton Council is sponsoring the work, and the Cotton Research Foundation is now serving as the technical agency.

The cotton problem appears to be far more complicated than the laymen or farmer who plants and tills the crop realizes. On the other hand, in the scientist's test tube, lint, seed, and stalk hold potentialities not even imagined before the quest began. For example, cottonseed hulls have been found to make an excellent floor sweeping compound. The stalk is being turned into building board, the linters are the basis of synthetic sausage casings, and also for rayon. Proteins are obtained from cottonseed meal. Wax is likewise being recovered from the cotton fibers. Much attention is being given to the study of tire cords, which have been an extremely important outlet for cotton, amounting to about 750,000 bales per year.

Other problems include water-proofing, fire-proofing and rodent-proofing processes, particularly for bagging materials for both industrial and consumer merchandising.

It should be emphasized that research is not a short-time remedy for economic ills. Experience has shown that a period of from five to ten years is generally required from the initial laboratory step to commercial production. Patience is therefore an essential ingredient of every sound research program.

Courage is equally important. One large manufacturer during the depression authorized a program of expansion when curtailment was the rule in the business world. The result has been a continuous growth in this particular food industry and many new products have been developed. Large lines of ready-to-serve soups, strained foods for babies, and junior foods have brought new products of high quality on the market. New methods of preparation of these products retain the vitamin, mineral salt and flavor contents.

Another outstanding development in the food industry during the past year is the new tenderizing beef process. The fact is that our patent system which requires full publication when the safeguarding contract —the patent—is executed has been an amazingly fruitful source of new inventions. Every meritorious invention that has been made and published as a patent has given numerous men new ideas and impelled them to create still other new things. A good example is the "Tenderay Process" for curing beef, which is based upon the "Sterilamp," a new source of radiant energy that possesses unusual properties as a sterilizing medium. The adaption of this lamp to cure meat has not only improved the palatability of beef through increase in tenderness and juiciness but has reduced the time of "hanging" from four to six weeks to three days. By acceleration of the reactions occurring in the beef there are avoided the large capital investment involved in "hanging" beef and the losses due to trimming and shrinking. In the period of days a tender product of superior juiciness can be produced in the price range of the general market without applying any treatment to the meat other than altering the atmospheric conditions under which it is hung. The general effect is judged as advancing the beef, at least one government grade, in general palatability. In the city of Cleveland where the process is being introduced, it has greatly increased the sale of beef from the stores handling this product. Additional plants are now being installed to meet the demands.

The research developments described, which have provided new industries or new products, have resulted from the active cooperation between aggressive capital and creative science. This kind of teamwork and a carefully planned research program will bring results of value. It is indeed a noteworthy fact that the time lag in the development of these manufactures has been reduced materially by a clear realization of the value of collaboration among the pure science research worker, the industrial scientist, and the industrialist. This cooperation is necessary to provide essential terminal facilities for all research work. Notwithstanding these great advances, however, scientific research is not at the peak of its power in any branch of technology.

The better living conditions secured through the increased wealth provided by science, together with the application of science to hygiene and medicine, have considerably increased the average expectance of life. This great achievement in public health is sufficient to justify the belief that those who call our industrial civilization mean in quality have narrow views and scant idealism.

Industry's activities and accomplishments in safety engineering and industrial hygiene are alone sound proof of this fact. The question of industrial health is not the single problem of a single industry. Neither is it an emotional nor sentimental problem. It is a practical problem for industry as a whole to solve. Statutes of themselves will not provide industrial health. As in the case of industrial accidents, industry has always shown a capacity, once it recognizes and confronts a problem realistically, to make steady progress toward its solution.

For every day's work lost by industrial employees because of accidents, an estimated 70 days are lost because of illness. Another authority claims that illness causes approximately 200 million lost working days each year. For this heavy loss the employer, the employee and the community pay and pay.

The problem of health hazards in industry, which in turn are related to illness, resulted in the formation of the Air Hygiene Foundation of America, in 1935. The Foundation, a non-profit, science organization, represents a cooperative effort upon the part of employers in behalf of industrial health. More than 200 companies in all lines of industry are supporting the work, the sole object of which is better health for America's 15,000,000 industrial workmen.

Through research grants, Air Hygiene Foundation is sustaining research at the following four centers of science: Harvard School of Public Health, the Saranac Laboratory, University of Pennsylvania, and Mellon Institute.

Industry is not only making progress in the abatement of atmospheric pollution but is also taking care of other wastes, such as stream pollution. A glance back over the past twenty years at the wastes problems of the iron and steel industry shows that atmospheric pollution from beehive coke ovens and blast furnace flue dust, coal tar, ammoniacal and phenolic liquors has

been largely abated, and that useful products are being recovered or manufactured from most of these wastes, from hydrogen sulfide recovered from fuel gases, and from slags. The greatly enlarged demand for tin and tin plate and other stock, especially for automobiles, furniture, office equipment, and the like, which require iron and steel surface-cleaned by pickling operations, has increased the importance of the waste pickle liquor problem. Extensive experimental work on this problem is in progress in the laboratories of several steel and chemical companies, at Mellon Institute, and certain universities.

Who said there were no more frontiers of industry to conquer? Who said, with the discovery and perfecting of the radio, aviation and the automobile, that man had conquered nature and the elements and had no where to turn to provide employment for an ever-growing world population? The mere recital of these few accomplishments of applied science in only one field, chemistry, should be sufficiently thrilling to revive faded ambitions and stir men to greater efforts in new and old fields of human endeavor. These disclosures should belie the word of defeatists. They should point to ever larger fields of employment for man, to say nothing of the conveniences they create for his comfort and enjoyment. ●

Research

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graduate and post-doctorate) and the purchase of apparatus and equipment required in connection with the prosecution of research. The Foundation exercises no control whatever over the selection of research projects or incumbents of the fellowships and scholarships. In this way there is little danger that the research work of the institution will be diverted into channels that are likely to result in discoveries that have a commercial possibility. If such might develop, it would be merely a by-product. In this respect pure science is fostered for its own sake.

What this has meant to the University of Wisconsin in the maintenance of its research activities may be seen when it is recognized that the Foundation's annual contributions have grown from $500 allotted in 1928, to a sum that now ranges from $175,000 to $185,000 a year. During this interim over $1,150,000 have been made available to the University.

In this University, research has largely paid its own way. The use of only the income from its invested principal means that perpetually in the University the future of a reasonable research program is assured.

This socialization of corporate profit for the benefit of the public at large rather than for the private individual alone has set a pace that has now been followed in one way or another by nearly two score other educational institutions, both state-supported and endowed.

This history of the Foundation records a new step in the development of higher educational effort. ●

Tanganyika

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simple lesson on the soil would cause us no embarassment. Nature study lessons can be followed very readily in most cases. However, we do not advance very far before we strike obstacles that require more than ordinary zeal on the part of the teachers if they are to be surmounted. I remember that shortly after the new course was published, the Father in charge of the class spent hours trying to get the wheels of a Tinker Toy set to work to demonstrate the laws of pulleys. Then there was the time I spent on an old auto horn to repair it and make it work as part of the course on electricity. Both of us spent much time trying to get

God's humble dwelling, Catholic Mission, Useri, Tanganyika, East Africa. The Congregation built this Church. They will build the next one when this one falls, but with manual training as outlined for the schools at present, the next one will be greatly improved. Catholics here number 1800. School children including catechumens, number 1100. They are the Church's hope.

enough parts of a storage battery together to make a cell only to find the cell would not work any way because the acid was seriously contaminated because the druggist had used an ordinary cork in the acid bottle instead of a glass stopper.

Our school lacks equipment for the lessons dealing with physics and chemistry. A few years back there was a drug store in the town seven miles away, but it had to be closed. It seems that it depended on cosmetics for profits, and the handful of Whites in the town bought very little of these. Now we send two hundred miles for chemicals that may not be in stock, and for apparatus that is never on hand. Orders are placed in London. Expensive equipment is out of the question because the schools have very little revenue, and most of this goes for food for the boarders and salaries for the teachers. Once the school almost got a microscope, but the donor preferred to have it put to use in a hospital.

The country has no gas; so a kerosene stove is used for heat. Water has to be supplied in buckets. The Father in charge of the course has to keep an eye on watch for anything that could possibly serve in his work. He collects here and there, and stores things of apparently no value, for he knows the course and knows what will help. ●

Chemical Gardening

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Arthur, Ernest Brundin and Rolland Langley, have placed this liquid culture technique on a scientific, commercial basis. Chemical gardening may now be used successfully for commercial crop production or for the satisfaction and entertainment of the average home gardener.

Chemiculturists divide themselves into users of sand culture, sub-irrigation, and water culture.

Sand culturists place their plants in pots, jars or tanks of a supporting medium of clean washed sand, preferably one of low alkali content, like limestone or dolomite. Then by a "continuous flow set-up" or a "drip reservoir" a solution containing chemical nutriment is fed the sand-imbedded roots.

The sub-irrigationists place their plants in a mineral aggregate support, too, usually gravel or cinders, but feed the chemicals to the plants differently. At regular intervals the large shallow containers are flooded with nutrient solution, pumped in from an attached reservoir or drain pit. This solution is then allowed to drain completely away, and the plant roots are left exposed to moist aggregate and air. After sufficient aeration the tanks are again flooded and the process repeated.

The water culturists lay mats of excelsior, sawdust, peat moss, rice hulls or similar absorbent material, on wire meshes, over pans or tanks of the nutrient solution, into which the plant roots dangle and enjoy an endless meal. Dr. William F. Gericke of the University of California is the United States' foremost practitioner of water-culture, to which he gave the name "hydroponics."

The growing of commercial crops according to the above methods is, in the words of the National Research Committee of 1937, "one of the most important technical developments of recent years."[1]

Certainly, making fresh produce available to the important Trans-Pacific Clipper base, Wake Island, as was done hydroponically by Lamory Laumeister under Dr. Gericke's guidance at the appeal of the Pan American Airways, early in 1938, bears out the Committee's contention. Today, Wake Island continues to enlarge its tank gardens and Pan American Airways purposes to use chemical gardens in other out of the way bases.[2]

The "chemiculture tomato farm" of Ernest Brundin, also under Gericke supervision, the two-acre tank farm of the California Packing Corporation, the thriving nutrient solution greenhouses and outdoor water culture establishments throughout the country suggest further the success in commercial fruit, flower and vegetable growing that chemical gardening offers.

In general, the growing of large quantities of crops within a comparatively small area, as is possible with this tank farming, and the growing of produce in desert regions, dust bowl areas and sandy wastes like Wake Island where soil growth is definitely "out," show further lucrative possibilities for chemiculture.

Progressive use of chemiculture is not confined to big commercial projects, like those discussed above, nor to the universities like California, Rutgers, Illinois and Wisconsin, that are doing special research in this field, but extends to amateur gardening and hydroponics clubs.

Increasingly important, too, is the part played by hydroponics in the classroom, where instructors use liquid culture to visualize botany. The Rolland Langley mentioned above, is a pioneer in this procedure. He originated a small hydroponics kit, complete with tank, tray, excelsior, rice hulls and plant nutrients, suited for school use. The trays can be lifted out of the tanks from day to day. The private lives of the plants, from bud to root, may be viewed and studied advantageously. (Just imagine the possibility of studying the antics of Vitamin B_1 on plants, thus openly!)

Some may yet be found who term chemical gardening a laboratory freak or a crazy California fad. But it has proved itself to have certain definite advantages over soil culture. To put these briefly we might say:

Chemical gardening allows:

Closer planting, and a corresponding conservation of space;

Freedom from common soil diseases, soil inhabiting insects, drought, floods, erosion and weeds;

Larger yields, as each square foot of hydroponics area is estimated to be the equivalent of five square feet of soil-garden in output, and three or four crops per year are possible in place of the one or two soil-produced crops;

Consistently uniform crops—as all elements essential to plant growth are under control in liquid culture, and the proper nourishment may always be supplied the plant;

Simplicity of operation, through electrically run automatic pumps, thermostats, etc.;

Better quality and more highly mineralized food products, since plants can be grown containing the proper balance of organic chemicals.

To those who attempt to discredit chemical gardening on the ground of its being too costly, we might add that the chemicals are cheap—commercial and fertilizer grade chemicals are all that are needed—and comparatively little water is used. Furthermore, electricity, used for the heating and lighting necessary, is becoming cheaper every year.

Indeed, the wildest chemiculture enthusiast does not hail chemical gardening as a panacea for all commercial and home gardening difficulties. The proper preparation for seed beds, containers, nutrient solutions, and the control of light, temperature, plant vagaries and their climatic adaptations, are still problems that require vigilant care and constant labor. But the most conservative must acknowledge that in chemical gardening the same benevolent Providence that watches over us, has opened to us new frontiers. ●

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Exhibits

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best a better result will be obtained. But the main advantage is in the development of teamwork. This quality which is so necessary on the playing field is also highly desirable in scientific work. The days of the alchemists, when scientific investigation was carried on in secret and the results of the investigators like Roger Bacon, were written only in cipher, are over. Now, the true scientist wants everyone to know what he is doing, partly in the hope that he may be helped by useful suggestions and partly to help others.

Finally, engaging in project making evokes in young minds the spirit of research. Research is the very soul of science. All the progress that has been made in science is due to it. But as more facts are brought to light, more mysteries are also revealed which clamor for solution. To accomplish this, more and more research workers must be developed. And while successful research work requires a special talent, it requires practice for its development. There is no better way to do this than to put science students to work on projects. While at the high school level the study of the textbook is mere memorizing of long-known facts, and ordinary laboratory work is simply a repetition of experiments performed over and over again, project making is at least a semblance of investigation and experimentation. There is an element of mystery in it which arouses the curiosity of the student to find a solution. There is the satisfaction that comes from the production of something new. Once a boy has really felt this thrill, he will never be satisfied with the humdrum life of merely repeating what others have said or done, but will dedicate himself to a life of creative activity even at the expense of physical and financial hardship.

So much for the benefits to be derived by the students from the making of exhibits. What good can come to the teacher from it? I suppose many science teachers will answer, "None. But, on the contrary, only extra work and worry." The preparation of exhibits does entail extra work. It is much easier simply to lecture and conduct laboratory work from already prepared manuals. Some teachers really do not have time for more. However, I have often observed that the teachers who have the most work to do are the ones who are most active in project work. The excuse of lack of time covers a multitude of sins, especially sloth.

The chief advantages to be derived by the teacher from directing project work are;

(1) That it makes teaching easier because of the effect it has on the students, as already described. It is a lot easier to teach a class that is interested and eager to accomplish things than it is to teach one whose members have to be prodded along against their will.

(2) It keeps the teacher from getting into a rut. We all have this tendency, and nothing hurts the teacher's effectiveness more than to go along year after year saying the same old thing in the same old way, with never a new idea or method.

(3) It stimulates the teacher, too, to engage in research. Of course high school teachers are not required to be research workers, but there is no reason why they should not spend part of their time in research. Most of them have, or should have, sufficient training in the sciences to carry on original investigation, because most of them have engaged in graduate work during their preparation. However, since it is not required, they are inclined to take the easiest way. But it is too bad that so many wonderful talents are thus being wasted. If a teacher became interested in directing his students in project building, it is more than likely that he would not stop there but would carry on a few private projects of his own. This might result in some very worth while discoveries that might benefit the teacher, even financially, and also benefit the school and the general public.

Some might agree with me that the students and the teacher would gain from preparing exhibits but might not see how this could possibly be of any value to the general public. The majority of people have neither the education to understand abstract scientific principles or processes nor the time or energy required to acquire a knowledge of them from books or lectures. But almost everyone is interested in looking at exhibits of scientific apparatus, especially if it is in operation. Crowds flock to fairs where such exhibits form a major part. But not everyone is able to attend such exhibitions. Hence it becomes the duty of the high school, especially in the country districts, to bring such scientific education to those adults who have not had the opportunity to acquire it in youth. By doing so the school also helps itself because many times when laymen see the interest and energy displayed by teachers and students in such things they will make donations to the science department for the acquisition of more and better apparatus.

Many of our great scientific foundations have come from laymen who were intrigued by work being accomplished under difficulties by self-sacrificing scientists. The late Mr. Charles R. Crane contributed liberally out of his own pocket and got others to contribute to the upbuilding of the great Marine Biological Laboratory at Woods Hole, Mass. No doubt all of us know of instances where laymen have been moved to give to institutions because of the outstanding work of some one professor or department. The science department has a unique opportunity to make its work known through the scientific exhibit. It should make the best of it for itself, the school and the public. ●

Hormones

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The Boyce Thompson experimenters report that the *control* plants of the holly went through the usual flowering period, the floral parts dried up and dropped off in two or three weeks. The plants, however, treated with indolebutyric or indoleacetic acids held their flowers longer than the controls and showed some development of the ovaries. The most striking results were obtained with naphthaleneacetic acid. *All* of the treated flowers set fruit, parthenocarpic development occurring without the opening of the flowers as shown in figure V.

The Inhibition of Root and Bud Development

Strange as it may seem, some hormones which exert growth promotion in leaf petioles and other stem-like organs, exert the opposite effect on roots. It has been shown that solutions of crystalline auxin-a or indoleacetic acid greatly retard the growth of roots. The effect would appear to be due to a specific reaction to the auxin, resulting in the acceleration of growth in stems and the inhibition of growth in roots.

Experiments with the Rose of Sharon (*Hibiscus Syriacus* L.), give results which seem to indicate an antagonism between synthesized root-inducing hormones and the natural shoot-producing hormones made within the plant itself. The Rose of Sharon contains a very active natural shoot-producing hormone since it is able to produce buds where no buds were after the naturally occurring buds are cut away. When these dis-budded cuttings are treated with vaporized root-inducing hormones, roots are developed and wound tissue is formed but *very few buds* appear.

Plant Hormones and Tropisms

Plants, as well as animals, make definite responses to certain stimuli. It has long been known that plants which are grown in the dark become long and thin; whereas those grown in the light are shorter and thicker. This indicates that the response to light is one of slowing down growth. Thus the side of the plant exposed to the light grows less rapidly than the shaded or darkened side. On this shaded side the stem is longer which permits it to curve directly toward the source of light. This response to light is called *phototropism* which means attraction to light. Until very recently this phenomenon was explained simply by the fact that light inhibits growth. Now it is believed that hormones are involved in this response. The tips of the stems are sensitive to light and it is at this region that an auxin is secreted and sent to the cells far down the stem where it produces growing effects. The cells that are directly stimulated by light are the ones which grow more slowly; they have done their part when they have sent out hormones to stimulate other cells to more rapid growth.

Plant tropisms are of various kinds. It may be observed that the axis of the young pine cone bends downward after pollination; this is now explained as differential growth which is probably caused by the presence of a hormone introduced by the pollen grains.

This knowledge of the tropic effects of natural hormones has been carried over into the laboratory. Here plant physiologists are synthesizing substances which artificially induce various tropisms. No doubt this knowledge will soon be put to practical use in plant culture.

Conclusion

An attempt to summarize the literature which has come off the press during the past few years, particularly the period between 1937 and the present, is not within the scope of this paper. The application and the results obtained by plant experimentation in the study of phytohormones are many and diverse. Probably no other phase of plant investigation has so much to offer both to the layman and to the practical grower. ●

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Microscopists

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exchange service is another important feature, with members buying, selling or exchanging books, instruments, specimens, slides and ideas.

All readers who are interested should communicate with the writer at 118 Water St., Chestertown, Md., mentioning this article and requesting an application-for-membership card or further information. Dues have been purposely kept to a minimum in order to bar no one. They are but fifty cents per year. Officers of the American Nature Association have been so favorably impressed by the success of the young society thus far that they have extended a special offer of a combination subscription to *Nature Magazine*, ordinarily $3.00 a year, plus an annual membership in the A.S.A.M. for a total of $3.00, and this applies to renewals as well as to new subscriptions, if sent through the writer. However, it should be stressed that the A.S.A.M. is an entirely independent group, with no commercial hookups of any sort. The *Magazine* has been acting as sponsor and optical companies have been assisting with literature, but the society must stand on its own feet and continue or fall according to the interest and cooperation of its members. Accordingly, all persons who would benefit by such a national body or who would like to see it succeed should get behind the movement and back it up by joining, thus insuring its permanent continuance. ●

Correlation

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examples. Let history trace the story of industry, commerce, of transportation, of communication, of the subjugation of nature for man's need, of the utilization of natural resources, of the downfall of aristocracy, the elimination of the proletariat, the rise of democracy with the high standards of living—the common laborer today has comforts kings could not have possessed years ago. And let our students see the part scientific research (after Christianity) has played in the dispelling of darkness, ignorance, fear and superstition; in the prolongation of human life, immunity from disease, relief from suffering, witness benefits of the radio and airplane in times of fire, flood and earthquake. If the discovery of a continent is deserving of historic recognition, why should the isolation of an element now found in all the far-flung laboratories of the world be relegated to a mere foot-note? Consider the blessings resulting from one single discovery, the X-ray. In forestry, to determine condition of trees; art, to detect copies from originals of the masters; dentistry, to diagnose diseases of the teeth; industry, to discern flaws (in the Westinghouse plant alone we had explained to us by Mr. Jennings, the operation of a 200,000 volt portable X-ray machine for examining massive weldings of iron and of steel); medicine, for treatment of certain diseases, especially tuberculosis, which may be cured if discovered in earliest stages; foot-troubles to determine what type of shoe should be worn. Why not let History clubs investigate such epics of heroism as Doctor Reed with his volunteers and yellow fever, Edward Jenner and small-pox, the mighty drama of the Curies, the achievements of Louis Pasteur, Doctor Koch and the tuberculosis bacillus, Ehrlich and salvarsan (the 606th synthetic compound he tried in his war on syphilis)? The real drama of such lives is far more gripping than any movie reproduction of a Stanley and Livingston. Adolescents are idealists, hero-worshippers, ready to admire courage and daring. Admiration leads to imitation. Who knows what embryo scientist history may discover for us! The teacher of science may secure from the social studies department lists of problems to solve in conjunction with laboratory work. (Problems in Health, Vocation, Domestic Affairs, Economy, etc.)

The Science Subjects

In order to minimize unpleasant overlapping it may be well for the teachers of the various science subjects to have informal meetings to decide upon techniques and procedures so that similar skills may be presented from different angles. Members of the classes may visit one another when special demonstrations are set up, permitting students to explain their principles. For example, osmotic pressure may be taught in inorganic chemistry by means of "The Silicate Garden"; in General Science, by the thistle tube, membrane and sugar water; in Biology, a battery jar of water in which are two eggs, the shell of one of which has been removed by acid.

Thus, there will be established a wide variety of logical associations according to the laws of similarity, contrast and contiguity. Allied phases of Physics and Chemistry are: the gas laws; the principles of the lift pump with that of sealing the tube while generating a gas; specific heat with thermo-chemistry; electroplating with the theory of Arrhenius on ionization and the electromotive series; the difference in potential and measurement of E.M.F. in a voltaic cell with conductivity of solutions and sharing and shifting of electrons; the color of spectra with organic compounds; the origin and propagation of light with the chemistry of carbohydrates. Biology and Chemistry are also closely allied: the simple processes of digestion, metabolism, secretion, excretion, are all chemical by nature; the development of the fish, the frog, the bird, the mammal have interesting chemical associations; the carbon cycle in both, as illustrated by the balanced aquarium, etc.

The biologist, by correlating with phychology has a real mission to perform. Our adolescents are not too young to be taught the sacred responsibilities of marriage, the physiological foundation of habit, the need of guarding one's thoughts, volitions and emotions, of keeping the body healthy and pure, and through the Mendelian Law of segregation to impress what was taught by Plato, Aristotle and St. Thomas that men from birth are of gold, of silver or of base metal, that is, heredity furnishes the *raw* material out of which our characters are fashioned. ●